The
ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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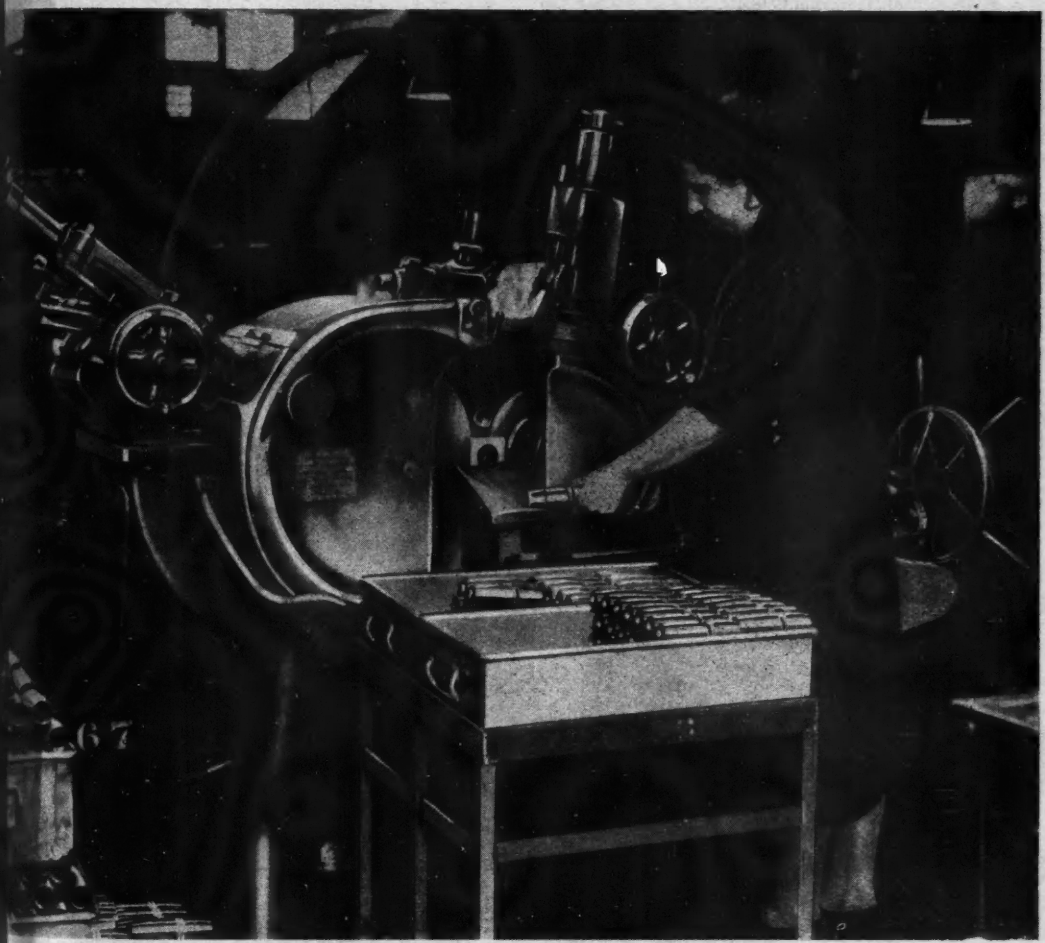

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REVIEW OF ENGINEERING PROGRESS ABROAD

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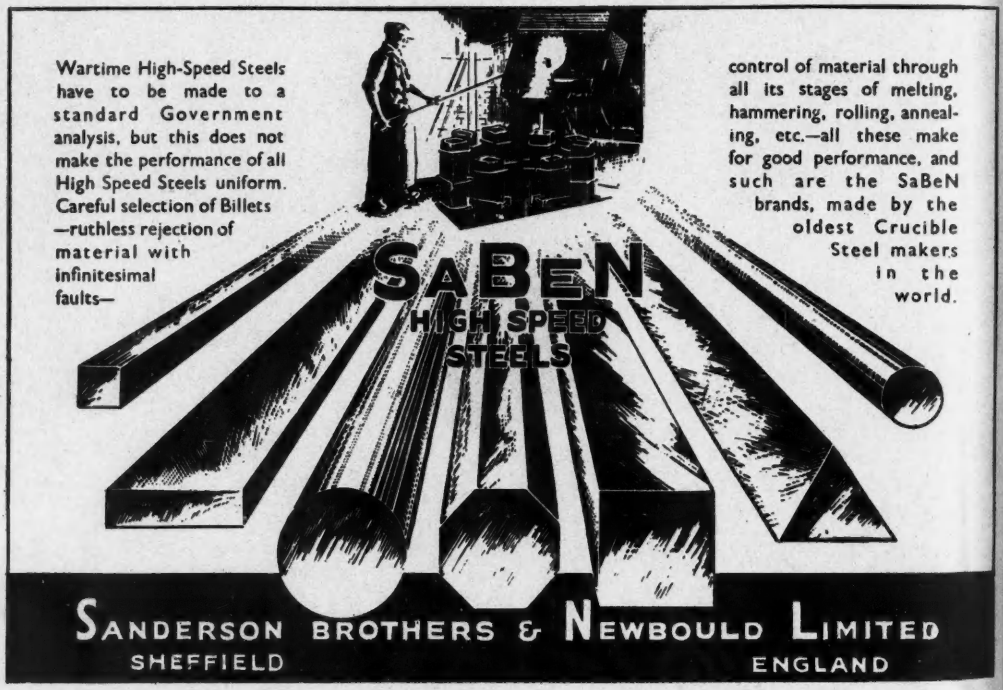
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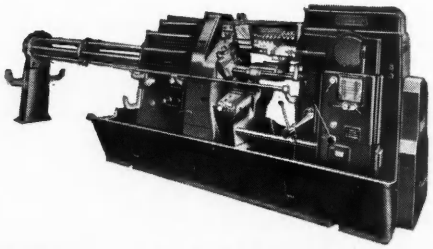

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A SWEDISH AERO ENGINE OF 2500 H.P.

(From "*Flyg*," Stockholm, Vol. 21, No. 18, September 9-22, 1943, pp. 21-24).

THE 2500 h.p aero engine designed by the Swedish engineer, F. Mannerstedt, is a 42 cylinder radial unit composed of six cylinder banks with seven cylinders each As Fig. 1 shows, the six radial banks are subdivided into two groups of three banks each, with the reduction gear arranged between the two groups. This arrangement also ensures improved cooling conditions of the three cylinder banks at the rear. The frontal area of the engine is 0.7 sq. metre corresponding to a diameter of 950 mm., while the overall length of the engine is 1900 mm.

With a cylinder bore of 110 mm. and a stroke of 110 mm., the cylinder capacity is 1.04 litres, making a total of 44 litres for the whole engine. The estimated engine weight is given as 950 kg. The two-speed two-stage supercharger is laid out to give full pressure at 1300 and 10,000 metres altitude respectively. Provision is made for the installation of a 20 or 37 mm. cannon in the hollow airscrew shaft.

In each radial bank, the cylinders are at an angle of 50 degrees to each other, with the exception of the cylinders at each side of the airscrew shaft, which are at an angle of 60 degrees. This is done in order to provide sufficient space for the strong, hollow airscrew shaft. The latter is driven by the aforementioned reduction gear placed between the two cylinder groups. This reduction gear arrangement also has the advantage that the maximum torque occurs in the middle instead of at the end of the crankshaft. Each cylinder group has its own crankshaft, the pinions of the front and end shafts meshing individually with the large gear of the airscrew shaft. This subdivision of the crankshaft greatly reduces its production cost, while the operating conditions of the reducing gear are considerably enhanced. A computation of the pinion stresses shows that a pinion width of 130 mm. is required to transmit the power; but with such a large pinion width, the risk of deformation of the teeth must be faced. But, by dividing the crankshaft, the width of each pinion is only 65 mm., which is quite normal. Another advantage accruing from the use of a divided crankshaft is that this results in a large distance between the front and rear bearings of the airscrew shaft, the actual distance amounting to more than half the length of the cylinder part of the engine. The result is an unusually high airscrew shaft stability.

The two cam shafts, for front and rear cylinder groups respectively, are driven from the airscrew shaft as indicated in Fig. 2. The other six cam shafts, driven by an oscillating ring, extend the length of the engine between the cylinder rows and are at a relatively large distance from the crankshaft centre. This permits of the use of short tappets ensuring a low inertia of the valve mechanism.

The cylinders are attached to the crank case by means of long tie-bolts, but shrink fitting of the cylinders may also be used in order to reduce engine weight. Two sparking plugs per cylinder are provided; these are inclined at an angle of about 30 deg. to the cylinder axis and are thus easily accessible.

The supercharger is of two-stage design with intercooler and two-speed gear. It is driven from the end of the engine shaft over a resilient coupling. The two-speed gear shown in Fig. 2 incorporates a planet gear train.

As the engine is designed for direct injection instead of a carburettor, the blower has to compress air only. At the higher speed with the gear ratio of 5.85/1 the blower operates at a speed of 21,000 r.p.m., with a peripheral impeller speed of 300 mm./sec., the impeller

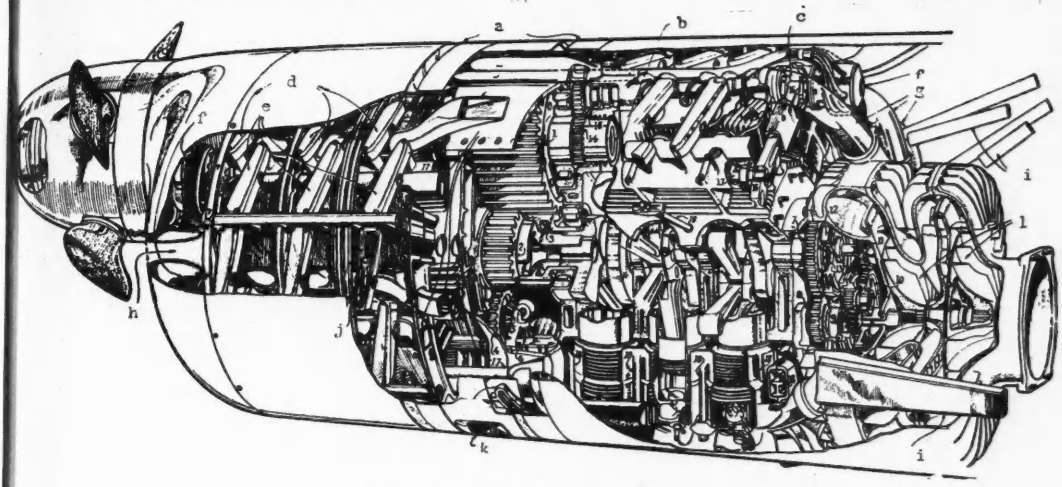
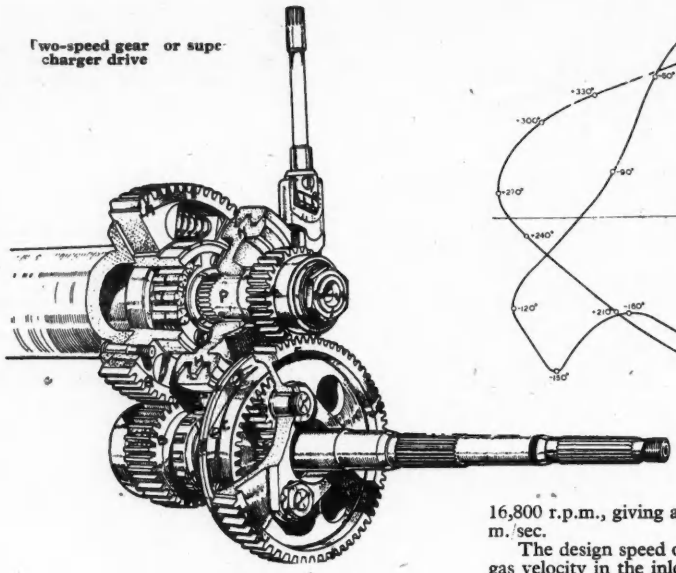


Fig. 1. **The new Mannerstedt engine**

1. Airscrew drive
2. Front engine-half drive
3. Rear engine-half drive
4. Oil pump main drive
5. Oil pump drive
6. Oil pump drive
7. Supercharge main drive
8. Supercharge gear shift
9. Planet gear-train drive
10. Planet gear-train secondary drive
11. Brake shaft secondary drive
12. Brake for planet gear-train
13. Gear shift coupling
14. Cam shaft drive
15. Cam shaft drive
16. Drive system of cam shaft
17. Cam shaft
18. Cylinder bolt

(*a*) Shutters for cooling air control
(*b*) Hollow shaft for cannon
(*c*) Crank on camshaft
(*d*) Exhaust valves
(*e*) Inlet valves
(*f*) Distributor
(*g*) Air supply
(*h*) Cooling air inlet
(*i*) Engine mounting
(*j*) Valve rocker
(*k*) Exhaust
(*l*) Two-stage supercharger

Fig. . Two-speed gear or supercharger drive



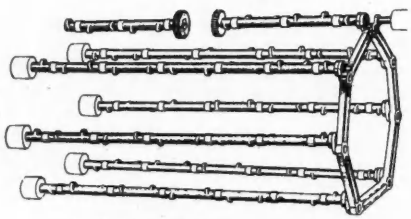


Fig. 3. **Cam shaft arrangement.**

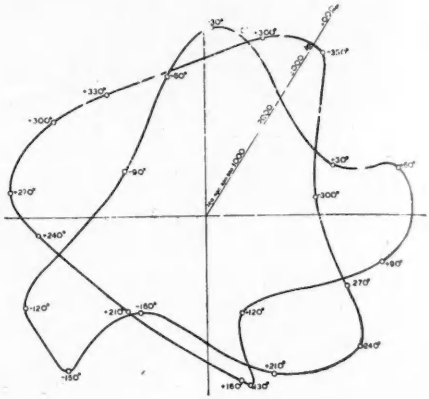


Fig. 4. **Distribution of total load upon crank pin of each cylinder bank.**

diameter being 33.3 cm. At the lower speed, corresponding to a gear ratio of 4.7/1, the blower speed is 16,800 r.p.m., giving a peripheral impeller speed of 288 m./sec.

The design speed of the engine is 3600 r.p.m. The gas velocity in the inlet valve is 60 m./sec., which is in complete agreement with modern practice.

The big end bearing is dimensioned on the basis of a specific bearing pressure of 100 kg/cm² at 3600 r.p.m., and of 170 kg/cm² for high speed. The piston speed of the engine is assumed as 13.2 m./sec., with a m.e.p. of 168 kg/cm². While no specific data are given with regard to engine weight beyond those given above, it is pointed out that the weight of the crank-case per h.p. is less than one-half of that of the Daimler-Benz 1100 h.p. engine. The same applies to the crankshaft, it is stated. Compared with the cylinder weight of the Bristol engine, that of the Mannerstedt engine should be lower by 40 per cent, and the same should hold true for piston rod and piston. All this goes to show that with the new engine a remarkably low weight per h.p. will be achieved.

SCREENING INVESTIGATIONS.

By S. MORRSELL and P. v. VILLNER. (From *Jernkontorets Annaler*, Stockholm, Vol. 127, No. 4, April, 1943, pp. 98-127.)

RECENT advances in the technique of mechanical separation are characterised by improvements in the design of vibrating screens and also by the development of new types of sieve cloths. It is because of these advances that mechanical separation by means of sieves is now being extended to still smaller particle sizes in the preparation of concentrates. Thus the lower limit to which the screening of slick or slick-containing material can normally be carried out without incurring undue complications, lies now at about 0.5–0.3 mm. particle size. It is, however, desirable to extend the use of sieves to still smaller particle sizes. In order to gain further insight into the problems involved, a special committee was set up by the special research department of Jernkontor to conduct a full investigation into the operating characteristics of fine sieves and related matters. This article represents the first report issued by the committee.

The following definitions were used in evaluating the various tests undertaken:

Total weight per cent. of raw material in excess over a given particle size = G_I per cent.

Total weight per cent. of raw material below the given particle size = F_I per cent.

Total weight per cent. above a given particle size limit in the material that has passed through the sieve = F_F per cent.

Total weight per cent. in residue—

(1) Of material above a given particle size limit = G_G per cent.

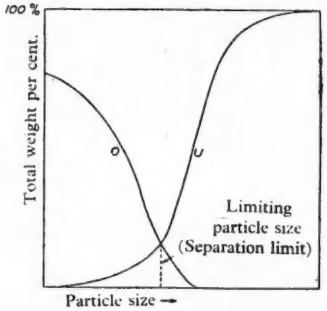


Fig. 1. **Limiting particle size for U = 0 (separation limit).**

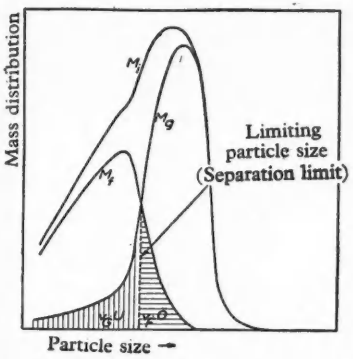


Fig. 2. **Limiting particle size for $v_G \cdot U + v_F \cdot Ö = \min.$**

(2) of material below the same particle size limit = U per cent.

Weight percentage of material passed through the sieve = v_F.

Weight percentage of material retained on the sieve = v_G.

The following equations can be established for the separating efficiency :—

$$v_G + v_F = 1 \qquad v_G = \frac{G_I - Ö}{G_G - Ö} \text{ and } v_F = \frac{F_I - U}{F_F - U}$$

Amount of oversize material retained on the screen $m_G = \frac{v_G G_G}{G_I}$.

Amount of undersized material which should have passed through the screen, but was retained on the screen, $m_{ö} = \frac{v_F Ö}{G_I}$

Amount of undersize material passed through the screen, $m_F = \frac{v_F F_F}{F_I}$

Amount of oversize material which should have been retained on the sieve, but has passed through the sieve. $m_U = \frac{v_G U}{F_I}$. $m_G = 1 - m_{ö}$, and $m_F = -m_U$.

On the basis of these definitions, the separating efficiency is established as

$$\eta_S = m_G + m_F - 1 = 1 - (m_U + m_{ö}) = m_G - m_U = m_F - m_{ö}.$$

If no oversize material can pass through the sieve, as

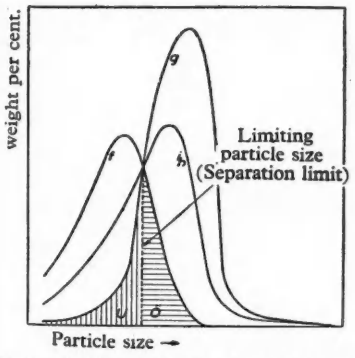


Fig. 3. **Limiting particle size for $U + Ö = \min.$**

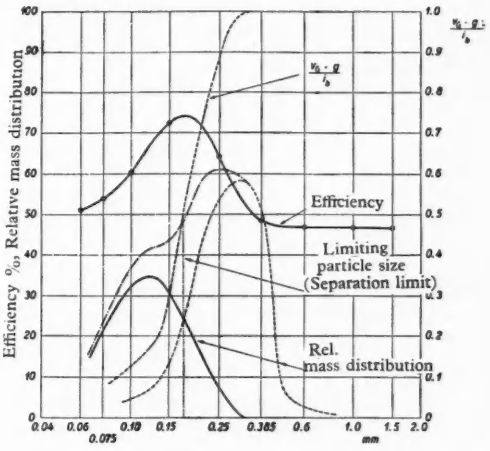


Fig. 4. **Curves for determination of limiting particle size (Separation limit). Limiting particle size = 0.17 mm. and separation efficiency = 73.2%. Performance satisfactory.**

for instance in the case of a sieve cloth with square meshes, it is

$m_{ö} = 0$, and consequently,

$$\eta_S = m_F = \frac{v_F F_F}{F_I} = \frac{(F_I - U)\ 10.}{(100 - U)\ F_I}$$

Limiting Size Range of Separation.

Furthermore, it is necessary to establish a limiting size range of separation, that is, a particle size limit at which the material is divided into the passed and into the retained fractions. This limiting size range can be expressed in various ways, among which the following were investigated :

(1) The limiting particle size for which the absolute amount of undersize particles remaining in the residue on the screen equals the absolute amount of oversize particles passing through the screen and contained in the final product : $v_G \cdot U = v_F \cdot Ö$

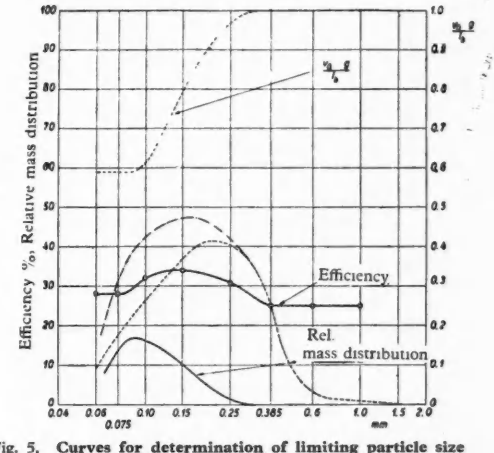


Fig. 5. **Curves for determination of limiting particle size (Separation limit). Unsatisfactory performance.**

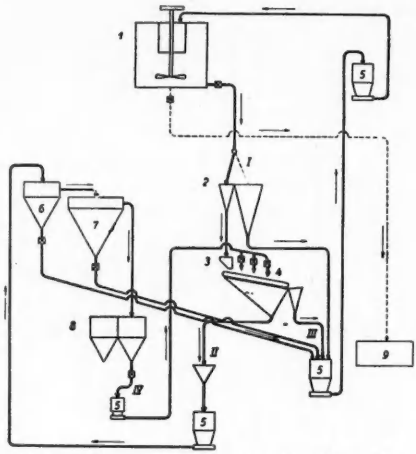


Fig. 6. **Diagrammatic representation of test plant.**

1. Mechanical mixer of about 5 cu. m. volume
2. Distributor
3. Weighing feeder device
4. Vibrating screen of about 0.73 sq. m. area
5. Pump
6. Hopper, about 0.9 cu. m. volume
7. Hopper, about 1.1 cu. m. volume
8. Clear-water container, about 1.0 cu. m. volume
9. Slime tank, about 8.0 cu. m. volume.

(2) The limiting particle size for which the percentage of undersize particles in the residue and that of oversize particles in the final product are equal, that is to say, for which $U = \ddot{O}$ (Fig. 1).

(3) The limiting particle size for which the limiting size class (*a*) is distributed in equal parts over residue and final product, that is, $v_G \cdot g_a = v_F \cdot f_a$.

Numerical values can be obtained from the mass distribution curve given in Fig. 2. Here the distribution curves for raw material, residue, and final product are represented by the curves M_i, M_g and M_f respetively. These are so drawn that $M_i = M_g + M_f$. It

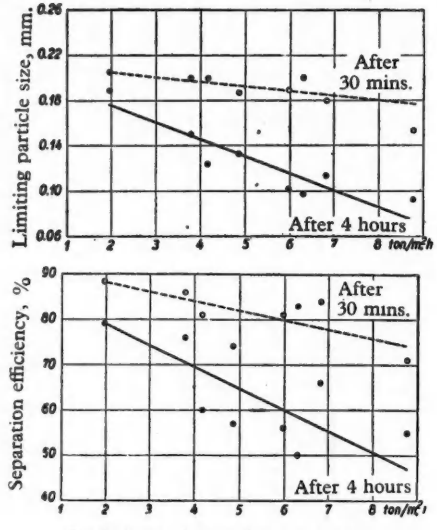


Fig. 7. **Typical saturation test results.**

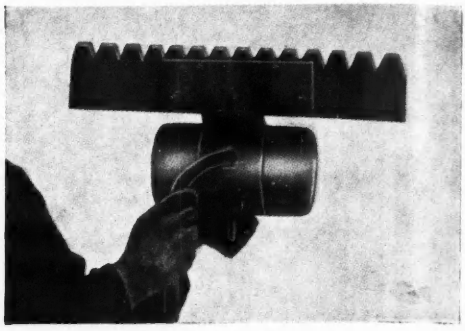


Fig. 8. **Vibrating comb.**

follows that the sum total of the areas under M_g and M_f are equal to the area under M_i. The limiting particle size is given by the point of intersection of the curves M_g and M_f. This means that the sum total of the absolute quantities of oversize and undersize particles, that is the hatched areas $v_F \cdot \ddot{O} + v_G \cdot U$ in Fig. 2, amount to a minimum with the limiting particle size.

(4) The limiting particle size for which the limiting particle size class is so distributed over residue and final product that $g_a = f_a$. The distribution curves are established in the usual manner, as shown in Fig. 3, where the areas under the respective curves are equal in extent. With this definition, the percentages of oversize and undersize particles, that is, $\ddot{O} + U$, are a minimum.

(5) The limiting particle size for which the separating efficiency is a maximum.

According to the definition actually chosen, the limiting size range is taken as the particle size of a narrow particle size class in the raw material which is so distributed by the separating process that one-half of it remains in the residue, while the other half is contained in the final product. In the evaluation of the test results, the graphical method shown in Fig. 4 was employed. Here the curve $\frac{v_G \, g}{i_b}$ represents the respective particle size class distribution over residue and final product. The limiting range, therefore, corres-

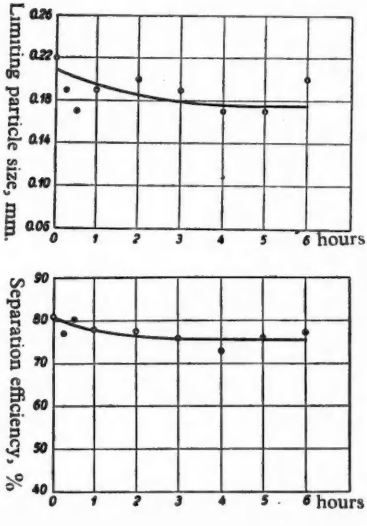


Fig. 9. **Typical results of saturation test with use of vibrating comb.**

ponds to the point at which the mass distribution equals 50%. Fig. 4 also shows the separating efficiency curve.

The graph given in Fig. 5 refers to a high load test conducted with a different and less suitable screen design. Compared with Fig. 4, separating efficiency is greatly decreased, while the $\frac{v_G\, g}{i_b}$ curve nowhere attains a mass distribution value of 50%. This is explained by the presence of an excessive amount of undersized particles in the residue on the screen.

The materials used for the various tests were preconcentrate of the magnetic separator plants at the Fagersta and Vintjäarn mines. The experiments were carried out with the vibrating screen plant of the recirculating type shown in Fig. 6, which made it possible to establish stable operating conditions in a comparatively short time with the use of a small quantity of material. Following upon a number of preliminary tests, the saturation tests proper were undertaken, in which the clogging of a sieve cloth of 0.22 mm. mesh was observed with different loads.

Referring to Fig. 7, it can be seen that separating efficiency is considerably influenced by the operating rate. Thus, for instance, a separating efficiency of 79% after 4 hours operation at a rate of 1.97 tons/sq. m. per hr., compares with an efficiency of only 55% if the operating rate is increased to 8.78 tons/sq. m. per hr.; but the progressive clogging of the sieve cloth also leads to a very marked decrease in the limiting particle size. Since the deterioration in the operating characteristics of the sieve is solely due to the cumulative effect of clogging, an attempt was made to keep the screen openings free by raking the sieve cloth at 10 minute intervals with a vibrating comb (Fig. 8). This led to a very considerable improvement in the performance characteristics as evidenced by the graph reproduced in Fig. 9.

GAS PRODUCERS FOR BUSES.

By W. Gumz. (From *Feuerungstechnik*, Vol. 31, No. 1, January, 1943, pp. 9-10).

In 1939, shortly after outbreak of war, the tram and bus companies in Stockholm started to build gas producers of the Svedlund Type (A. B. Hägglund), operating on charcoal. As they were built into the rear of the bus, a rather unfavourable distribution of the load on the body of the bus has resulted from that design. Attempts were, therefore, made to alter the design in order to distribute the load more uniformly over the whole body. 65 of these buses were fitted with producers up to the middle of 1940, when it was decided to change over to producers of the two wheel trailer type, consisting of the actual producer, gas cooler, purifier, and bunker of appropriate size. At the end of 1940, 190 of these trailers, using charcoal as fuel, were operating, fitted with a bunker of 9 hl capacity and thus being able to run continuously for six hours without having to refuel.

The purifying plants proved unsatisfactory until it was decided to build in cyclon fans. The so-called safety filter had to be improved as well, as due to the burning of the gas in the long pipe lines between producer and engine, the filter cloths of the purifiers were often burned. In addition, safety valves were built into the pipe lines. Owing to the connection of the throttle valve with the blower for starting, it sometimes happened that the vacuum created caused the fuel container to buckle in. This trouble was overcome by means of a loaded flap valve providing the entry for the primary air. The example also illustrates the fact, that the question of purifying the gas is of the utmost importance in the development of producers for vehicles; generally, insufficient consideration is given to this problem, and many designers feel they have to improve or redesign the producers, completely forgetting their main problem of supplying a sufficiently pure gas.

At the beginning, considerable trouble was experienced through the quality of the fuel, especially owing to the formation of clinker in the producer. This, however, occurs only with charcoal; no such difficulties are experienced with first class coal, with which there is practically no clinker formation. However, even with first class coal, difficulties occasionally arise from clogging of the filter cloths which may be caused by deposits of tar, and under certain circumstances through the use of too wet fuel which results in deposits of tar, soot and dust. Clogging of the filters can reduce the engine output considerably and can even stop the engine. The engine output is also reduced considerably just by changing from petrol to producer gas, thus the use of unsuitable fuel can become very noticeable. The best results were obtained with pure birch wood charcoal. The proportion of pine in the charcoal should not exceed 20% as otherwise the dust content is too high. The lower cost of the cheaper mixed charcoal offers no advantage.

A thorough training of the drivers is considered of extreme importance, on the one hand to obtain the most economical operating conditions, and on the other hand, to prevent accidents from explosions, burns, and gas poisoning. The operating costs are especially high as this particular company keeps a special staff of 100 men working in three shifts who are responsible for the maintenance, cleaning and fueling of the vehicles. In addition, the cost of charcoal is very high compared with the normal price of liquid fuel.

Charcoal is also undesirable from the economical point of view, 2.5 times the quantity of wood being required to obtain the same output, neglecting the value of the by-products. This was the reason in 1941 for changing over more and more to the producer of the Hesselman type using wood as fuel. With regard to volume, the fuel consumption with wood and charcoal is roughly the same, i.e., about 0.06 hl/km. However, the weight of a hl of charcoal is roughly 16 kg, while the weight of the same volume of wood of moderate moisture content is roughly 30 kg. With an annual run of 7.5 millions km the difference in price becomes of considerable importance, the cost of charcoal being 25 Öre/kg, that of wood being 8 Öre/kg. This corresponds to a cost in fuel of 11.25 Öre/km with charcoal, against 7.20 Öre/km with wood for an average lorry.

Wood has several advantages over charcoal used as fuel in producers (e.g. formation of clinker) the disadvantages, however, being the necessity of removing the condensate during the time of operation, and certain difficulties encountered in winter, viz., the daily flushing of the cooling and purifying systems. To overcome this difficulty of flushing, a special drain with hot water was developed which has proved satisfactory and can be kept at a temperature of $+5°$ when the outside temperature is $+30°$; the water is heated electrically. The flushing carried out through the cork-purifier, wet-purifier, cooler and cyclon, requires a quantity of water of 300 to 400 litre/min., the time of flushing being less than one minute. It is advisable to use wood which is as dry as possible. The maximum permissible moisture content should be 18%; with a moisture content of more than 30% various difficulties can be encountered. The moisture content of the wood is checked by means of a Siemens electric hygrometer.

When the producers are opened for refuelling or for other reasons the gas escaping at the top is lit for safety reasons by means of an electric lighter. The expenses for repairs were much lower with gas producers operating with wood than with those operating

with charcoal, especially as through the removal of clinkers the grates and the lining are often damaged, thus the number of spare parts required being rather high. With producers operating on wood deformations of the hearths and tears in the pipe lines for the primary air often occurred, this, however, being mostly due to leaks in the covers which can be prevented by careful use of graphite lubricants to obtain tight joints.

The engine wear is undoubtedly higher than with liquid fuels, although it cannot be entirely attributed to the use of producers, as at the same time special lubricants had to be used which also partly account for the increased engine repairs. The oil contamination is not especially high; previously the oil was changed every fourth week. The oil is reclaimed in special cleaning plants. The clean oil obtained in this way is equivalent to the new oil. However, the oil consumption of the engines is relatively high, and by the daily topping-up the oil it is continuously being renewed.

Finally, the high duty of the electrical equipment should be pointed out, resulting in a corresponding high consumption of batteries and electrical equipment. In order to overcome these disadvanatages special batteries on wheels have been provided for starting in the yards of garages,thus saving the batteries built into the vehicles. The buses are not driven into the garages or started there with producer gas but a number of tractors operating on methane have been provided for this purpose. Actually the buses are being supplied again with methane bottles, so that they can drive under their own power in and out of the garages; the producers are prepared on the yard of the garage and are coupled to the buses, so that the driver can switch over from methane to producer gas. Finally the importance of taking measures against gas poisoning should be pointed out. By regular examination of the gas this danger was substantially dealt with, but still more by eliminating people specially sensitive to gas poisoning. Nevertheless, cases of poisoning still occur so that thorough instructions about this danger and greatest care in the organization are essential

TINNING OF LIGHT METALS BY MEANS OF ULTRASOUND.

By A. E. THIEMANN. (From "*ATZ Automobiltechnische Zeitschrift*," Vol. 45, No. 24, 25th December, 1942, p. 668.)

IT is well known that the presence of a thin oxide film on the surface of light metals greatly impedes the application of a coating with other metals. For this reason, it is most significant that the employment of ultrasound waves has been found to make possible the tinning of thin aluminium sheet. Thus, softening of aluminium sheet has now become possible, hereby opening up new avenues to the employment of aluminium sheet.

The new process consists of dipping the aluminium sheet into a bath of molten tin, at the same time contacting the sheet with an ultrasound generator. The ultrasound vibrations transmitted to the aluminium sheet in this way are in turn transmitted to the tin film surrounding the sheet. The enormous accelerations and decelerations hereby imparted to the tin particles serve to remove the adherent layer of oxide, its place being taken by a layer of tin intimately bonded with the virgin aluminium surface.

Being of the order of more than 12,000 vibrations per second, ultrasound waves are inaudible to the human ear. With a velocity of sound in air of 330 m. per second, ultrasound waves comprise a range of wave lengths extending from 16 mm. to 0.005 mm., while in liquids with a velocity of sound of 1200 mm. per second, the wave lengths range from 60 to 0.002 mm. The shortest of ultrasound waves, therefore, approaches the wave range of visible light.

With an ultrasound frequency of 300,000 per second, metal particles vibrating at this rate attain velocities of about 40 cm. per second through a vibration amplitude of about 0.001 mm., the resulting acceleration being of the order of 1000 to 10,000 times the gravitational acceleration. It is easily seen that the removal of the oxide film from the surface of the aluminium sheet is directly due to the hammer-blow-like impact of the vibrating tin particles. The intensity of sound achieved at ultrasound frequency can be gauged from the fact that an ultrasound generator permits of the generation of sound intensities up to 10 watt per sq. cm. as compared to that of about 0.001 watt per sq. cm. released by the firing of a cannon.

Owing to the small wave lengths of ultrasound, pressure gradients as large as 10 atmos. per mm. are set up, which in themselves explain the enormous accelerations imparted to the particles of the liquid. In the case of solid particles, these accelerations may even lead to the disintegration of the particle. This phenomenon is used for the improvement of cast materials by exposing the resultant disintegration of the nascent crystals augmenting the number of nuclei, and thus producing a finer structure.

Ultrasound waves can also be used for producing an extremely fine dispersal of solid particles in liquids—that is, to produce mixtures of ordinarily immiscible materials. In this way, a self-lubricating bearing bronze containing 25 per cent graphite in homogenous mixture with the metal can be produced.

Generation of ultrasound waves is carried out by means of alternating current of a frequency equalling that of the ultrasound waves to be produced. This current is passed through the coil of a solenoid, the core of which consists of a short piece of tube of an 80 per cent nickel, 20 per cent iron alloy. By adjusting the frequency of the current to produce resonance with the mechanical frequency of the core, the contraction and expansion of the core under the influence of its magnetization can be greatly increased.

The simplified circuit diagram of an ultrasound generator of this type is shown in Fig. 1, where (1) is the ferromagnetic core of Ni-Fe alloy, and (2) is the magnetising coil passed by the high frequency current, the frequency being adjustable by means of the variable condenser (3). Oscillation of this circuit is effected by means of the electronic valve (5) and the regenerative coil (4). Core (1) is premagnetised by battery-supplied direct current passing through coil (6) and being adjusted by the variable resistor (7).

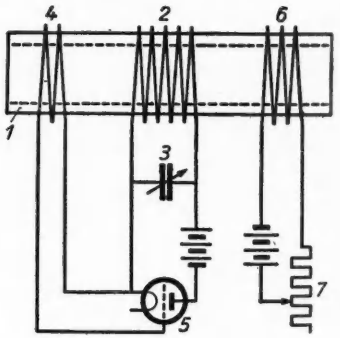


Fig. 1. Simplified circuit diagram of an ultrasound generator operating on the principle of magneto striction.

MODERN HARDNESS TESTING MACHINES.

By Von Dipl.-Ing. Kurt Meyer, VDI, Berlin. (From *Werkstatt und Betrieb*, Vol. 76, No. 3, March, 1943, pp. 51-53).

The Rockwell "Testor" is a universal testing machine suitable for all three static hardness measurements. Types HT1 and HT2 are specially worth mentioning. Two further types, HE3 and HE4, are also used for Brinell tests with high loads up to 3,000 kg. These hardness testing machines use depths of penetrations magnified in the ratio 5:1, and are fitted with a dial gauge. In the types HT1a and HT2a, used mainly for Rockwell hardness measurements, the initial load is applied through a loading lever and a weight. The maximum load that can be applied is 250 kg. The penetrator is mounted on roller bearings in order to decrease and obtain a more uniform friction.

In a large number of instruments mentioned below, the minor load is applied by the weight of the unloaded lever, while the major load is applied by a weight placed on the loading lever. The minor load is, therefore, fixed. The maximum load again is 250 kg. and the depth of penetration is magnified in a ratio 5:1 indicated on a dial gauge.

A hardness testing machine named "Welltest" (Fig. 1), is made in different heights, but the loads are always the same.

The machine KPH 250 (Figs. 2 and 3) is made in two different sizes with different loads and test heights. While in the previous machine the minor load was applied by lifting the test specimen against the penetrator until the dial gauge indicated a definite reading, in this instrument the minor load is applied by a special lever *g* which releases the weight of the loading lever. By pressing the lever further down, the major load is applied. The frictionless guide of the penetrator socket used in these instruments is specially mentioned.

The latest instrument of this kind is the "Zet 13" (Figs. 6 and 7). In construction and operation it is similar to the other instruments of this type. The mounting of the penetrator in this instrument is, however, worth mentioning. The penetrator socket is pivoted in a roller bearing in its lower part, the upper part being shaped like a cup into which the loading lever fits, and any lateral movement of the penetrator during application of the load is prevented, and exact centering is achieved. In design the "Welltest" hardness testing machine is similar.

SPECIAL INSTRUMENTS.

The "Ultra Testor" (Fig. 8) measures the depth of penetration of the cone directly without any magnification by a lever. But in measurements of that kind the dial gauge is not sufficiently accurate and the percentage error of the measurement is too large; the "Orthotest" which is a lever type instrument is therefore used instead. After applying the minor load the pointer on the scale is set to zero by shifting the scale, it is thus possible to read off directly the Rockwell hardness of the specimen. Loads that can be applied with this instrument range from 5 to 250 kg. These loads are produced by means of weights. As very low loads can also be applied, it is possible to measure the hardness of thin hardened parts, metal sheets and specimens made of non-metals. All specimens can be tested which are unsuited for the usual Rockwell hardness testing machine. Two minor loads can be used, viz. 350 g and 10 kg. which make it possible to carry out minor load tests with smaller major loads for the sake of comparison with the normal Rockwell test. For this purpose, special tables are provided with the instrument, from which comparative figures are obtained and the actual Rockwell hardness numbers determined.

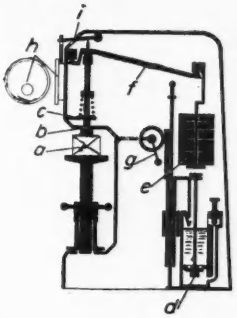


Fig. 3. Diagrammatic section. Hardness testing machine KPH 250.
(*a*) test specimen; (*b*) penetrator socket; (*c*) frictionless guide for penetrator; (*d*) oil brake; (*e*) additional load; (*f*) minor load lever; (*g*) operating lever; (*h*) dial gauge; (*i*) magnifying lever (5:1).

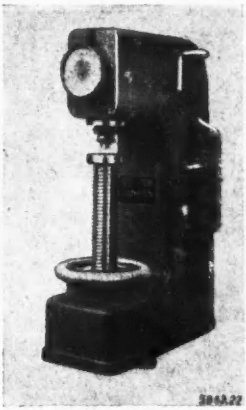


Fig. 4. Hardness testing machine HT 2a. Manufacturer: Wolpert-Werke, Ludwigshafen.

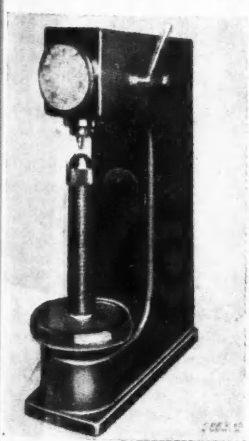


Fig. 1. "Welltest" hardness testing machine, Manufacturer: Frank, Mannheim.

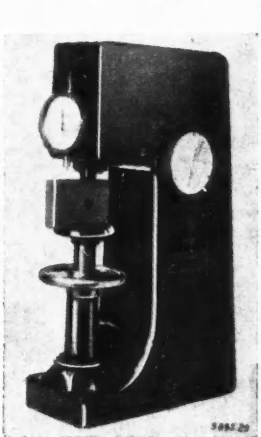


Fig. 2. Hardness testing machine KPH 250. Manufacturer: Louis Schopper, Leipzig.

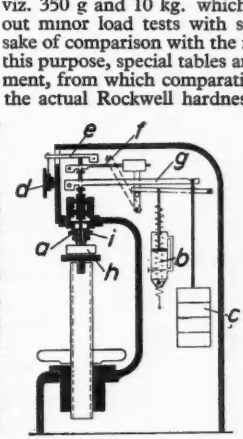


Fig. 5. Diagrammatic section HT2a hardness testing machine.
(*a*) penetrator socket; (*b*) oil brake; (*c*) loading weight, (*d*) dial gauge; (*e*) magnifying lever (5:1); (*f*) loading lever for minor load; (*g*) loading lever for additional load; (*h*) test specimen; (*i*) clamping cap.

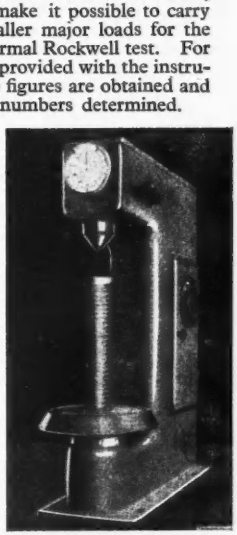


Fig. 6. Hardness testing machine "Zet 13". Manufacturer: Zwick, Ulm.

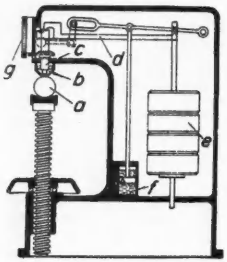


Fig. 7. Diagrammatic section, "Zet 13," hardness testing machine.

(*a*) test specimen ; (*b*) clamping head ; (*c*) penetrator socket ; (*d* minor load lever ; (*e*) additional load : (*f*) oil brake ; (*g*) dial gauge ; (*h*) magnifying lever (5:1).

Fig. 8. Hardness testing machine, "Ultra-Testor." Manufacturer : Wolpert-Werke, Ludwigshafen.

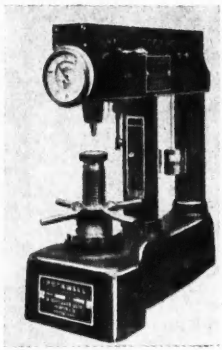


Fig. 10. "Super-Rockwell" hardness testing machine. Manufacturer : Koyemann Düsseldorf.

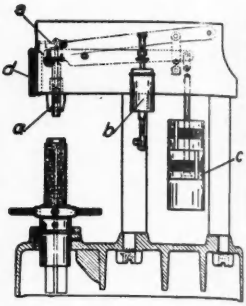


Fig. 11. Diagrammatic section, "Super-Rockwell" machine.

(*a*) penetrator socket ; (*b*) oil brake (*c*) loading weights ; (*d*) dial gauge (*e*) magnifying lever of depth of penetration.

The Super-Rockwell-Surface hardness machine (Figs. 10 and 11) is used for testing thin hardened layers, nitrided specimens, thin metal sheets, tubes, soft non-metal specimens, by measuring the depth of penetration by differences similar to the Rockwell method, only with smaller major loads. In construction and operation it is similar to the standard Rockwell machine, the test loads of this instrument, are, however, much lower. The minor load is 3 kg. and the main loads, minor and major loads, are 15, 30, and 45 kg., the depth of penetration of a normal Rockwell cone for hard specimens and a $\frac{1}{16}$-in. diam. steel ball for soft specimens being very slight. If on a hardened tool steel the depth of penetration with a standard Rockwell load is 0.100 mm., the cone of the Super-Rockwell machine with a major load of 30 kg. will give a depth of penetration of roughly 0.025 mm. for the same material. A dial gauge is used as a measuring instrument for the depth of penetration which again is magnified by the lever ratio, and tables give the Rockwell numbers for the major loads of 15, 30 and 45 kg.

A further instrument used in the same manner as the Super-Rockwell is the Briro UVK (Reicherter, Esslingen) hardness tester.

All instruments mentioned above used on the Super-Rockwell method are also suitable for Brinell and Vicker's tests at low loads if appropriate penetrators are used. The hardness numbers must be determined outside the instrument by means of an accurate measuring microscope.

Testing machines are still in use by means of which loads in the region of 3,000 kg. can be applied and are higher than specified for standard Rockwell tests ; such instruments are manufactured by Reicherter, Esslingen. The instrument BRF is an example, its maximum load being 3,000 kg.

Fig. 12. Bracket for internal Rockwell hardness testing. Type : Frank, Mannheim.

Fig. 13. Rockwell hardness test of a ring. Type : Gg. Reicherter, Esslingen.

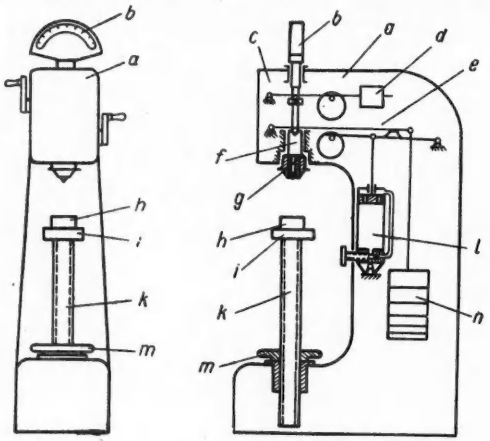


Fig. 9. Diagrammatic section, "Ultra-Testor"

(*a*) casing ; (*b*) Orthotest gauge ; (*c*) minor load lever ; (*d*) minor load weight ; (*e*) major load lever ; (*f*) penetrator socket ; (*g*) penetrator ; (*h*) test specimen ; (*i*) test table ; (*k*) spindle ; (*l*) oil brake ; (*m*) hand wheel ; (*n*) major-load weight.

INSTRUMENTS FOR INTERNAL ROCKWELL HARDNESS MEASUREMENTS.

In most cases a special instrument for internal hardness measurements will not pay, especially if only a limited number of specimens are to be tested. Instruments of that kind exist, but their purchase seems only justified for mass-production purposes. In general, the usual Rockwell machine will suffice if adapted with a special bracket for internal measurements as shown in Fig. 12. This can be inserted in a simple manner and the penetrator is mounted on the horizontal part of the bracket which is of specially rigid construction to prevent the formation of ΔF values caused by the deflection of the bracket. The strength of the bracket is limited by the dimensions of the test specimen. Obviously the weight of this bracket has to be accounted for in the minor and major loads. Fig. 13 shows the construction of a bracket used for making hardness measurements on a thin ring of large diameter, the ring being clamped at the same time.

Finally, a clamping method should be mentioned as recommended by Reicherter, Esslingen, the so-called "Indirect Clamping." This method is used especially for specimens of very small size which cannot be fixed

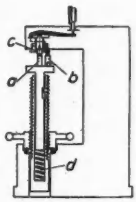


Fig. 14. Indirect clamping of test specimen suggested by Georg Reicherter, Esslingen. (*a*) test specimen ; (*b*) auxiliary test specimen : (*c*) test head ; (*d*) clamping spring.

by ordinary means and thus their hardness cannot be determined properly by the Rockwell method. In such cases a satisfactory solution can be achieved if another auxiliary test specimen *b* is used which, by means of a test head *c* is fixed in place of the specimen *a* in the testing machine (Fig. 14). This, of course, presumes that the test specimen and the auxiliary specimen have the same height. By means of indirect clamping it is possible to eliminate errors caused by the testing machine resulting in ΔF values. The possibilities of errors remaining are those caused by the test specimen itself ; these, however, are negligible. The method of indirect clamping is used to a great extent in hardness testing of small screws.

NEW CONTACT TYPES FOR SWITCHGEAR.

By F. HENKER. (From *ETZ*, Vol. 64, Nos. 25/26, 1st July, 1943, pp. 347-349).

ON account of its good conductivity and its almost negligible oxidation, silver is still considered as one of the best available contact materials.[1] Even when breaking fairly large currents with the occurrence of arcing, there is little burning or evaporation. When breaking direct current, peculiar changes in weight and shape of the contacts occur after two million or so switching cycles (Fig. 1). However, with alternating current, a uniform burning-off is registered and a clean contact surface nearly always remains, although considerably diminished in size.[2]

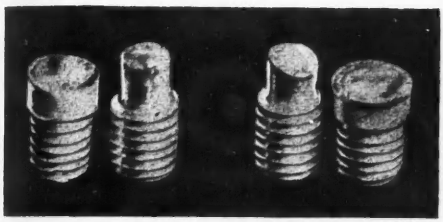


Fig. 1. Silver contacts, operated with 12 V. d.c. The large contacts at the extreme right and left have 25 sq. mm. contact area and were loaded with 15 A. The inner contacts have 10 sq. mm. contact area and were loaded with 10 A.

The test apparatus shown in Fig. 2 essentially consists of a number of striking contacts[3], of each pair of contact points one point being movable, and the other stationary. This contact type was chosen because it represents the most commonly used type, and at the same time possesses least favourable contact conditions as compared to contact of the sliding or rolling, etc., type. Making and breaking of the contact at the average rate of 220 times per minute was effected by a motor-driven cam and roller device ; this speed corresponds to about 3.7 breaks of contact per second, the contact remaining closed for about one-third of the interval between breaks. This high rate of contact operation was chosen in order to establish a standard based on severest possible operating conditions.

Time relays in the contact circuit were used to trip the motor circuit whenever contacts failed because of oxidation. Failures of this kind, however, were experienced only with the use of copper contacts. Silver or high grade silver alloy contacts did not show failures on account of oxidation.

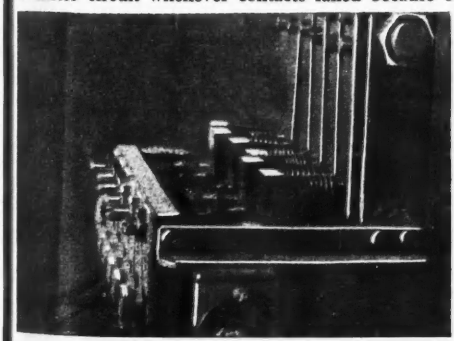


Fig 2. Contact testing device.

For the sake of greatest possible utilization of contact surface, a standard contact area of 10 sq. mm. was chosen, the contact pressure averaging 0.25 kg/sq. mm. In testing copper contact points with 110 volt d.c. and 2.7 amperes, 6,691 switching cycles were performed. By this time, the contact surfaces had turned black, but burning had not occurred as yet. The contacts were then cleaned and the test resumed. After further 6,000 switching cycles, an incandescent spot on one of the contact surfaces appeared, which spot had considerably grown in size after 30,000 switching cycles. While the cupric oxide remained a conductor as long as it was in incandescent state, this property was lost after a short cooling period (Fig. 3). At the commencement of the test, contact resistance had been ascertained as 0.0002 ohm.

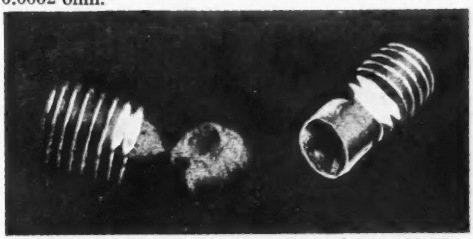


Fig. 3. Copper contacts after 30,000 switching cycles at 110 V. 2.7 A.

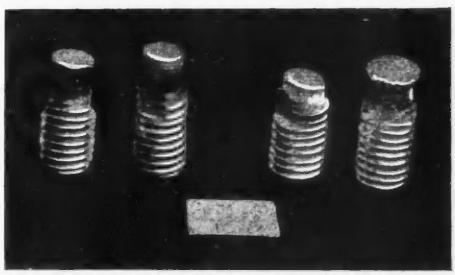


Fig. 4. Comparison of special alloy contacts (l.h. side) with silver contacts (r.h. side) after 1 million switching cycles at 600 V. 0.32 A.

With two fine-silver contact points, on the other hand, 446,000 switching cycles could be performed under identical operating conditions. In the end, one of the contact points had almost completely worn away. After this comparatively small number of switching operations, the negative point of contact was found to have already lost 11.5% in weight, while the positive point had gained 1.41%. Since the burning of the silver was believed to be due to its inherent softness, a number of silver alloys were tried out which had Brinell hardness up to 160 kg/sq. mm., and in some cases up to 200 kg/sq. mm.

With alternating current, these alloys proved successful only for voltages up to 220 volts, and with direct current for voltages below 12 volts. Some of these alloys are particularly well suited as non-oxidizing material for spring contacts. This applies in particular to telecommunication circuits[4] and similar arrangements in which greatest service reliability is absolutely essential, less stress being laid upon high amperage.

Tungsten-silver contact points of a 25.6% silver, and 74.2% tungsten alloy, were examined in the same

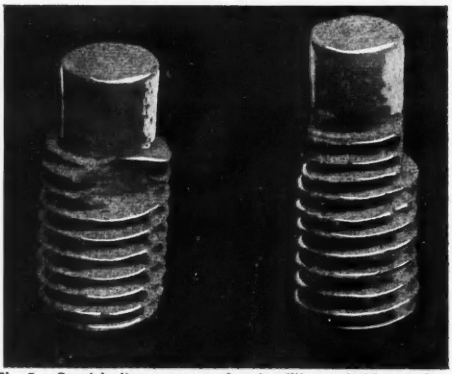


Fig. 5. Special alloy contacts after 3 million switching cycles at 600 V. 0.32 A. d.c.

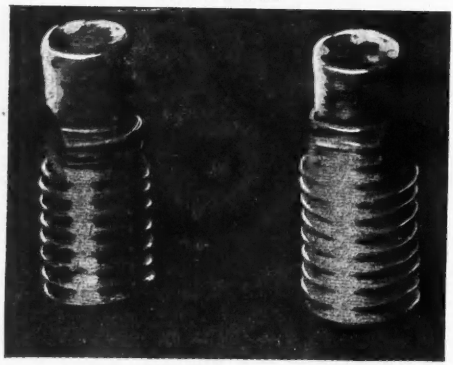


Fig. 6. Special alloy contacts after 3 million switching cycles at 380 V. 5 A. a.c.

way, but these showed a high rate of burning and very high contact resistance. They proved satisfactory only for less than 12 volts d.c. Finally, contacts with each point made of a different material were also investigated, a high percentage silver alloy being chosen for the positive, and a high percentage copper alloy for the negative contact point. This type proved to be extremely successful, showing hardly any wear at all after three million switching cycles. The combined loss in weight of both contact points was found to be no more than 2.96%. A peculiar feature is that contact resistance is smaller in cold state than during operation; its actual value in cold state amounting to 0.006 ohm.

With this type of contact, the cuprit oxide formed, failed to act as a non-conductor, and burning of the silver contact after three million switching cycles was almost imperceptible. But it should be noted that a change in polarity, that is, making the copper alloy serve as positive and the silver alloy as negative point of contact, resulted in considerable and rapid wear.

A test run at 600 volts d.c. proved equally successful. Although contact resistance was considerable during operation, it was very low in cold state (Figs. 4 and 5). After three million switching cycles, the positive contact point (of alloy No. 15) had lost 1.25% in weight, while the negative point (of alloy No. 16) had lost 2.9%, the contact pressure averaging 2.54 kg/sq. mm. In order to make the arc self-extinguishing, the amperage had to be limited to 0.32 amperes.

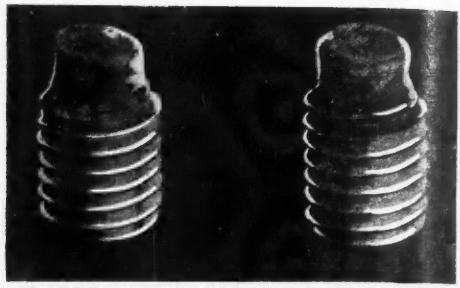


Fig. 7. Silver contacts after 2 million switching cycles at 220 V 6 A. a.c.

The mechanical properties of alloy No. 15, which contains 90% silver, are most important in so far as it combines a tensile strength of 60 kg/sq. mm²,[5] with a Brinell hardness of 160 kg/sq. mm.². This compares with a tensile strength of only 29 kg/sq. mm. and a Brinell hardness of 60 kg/sq. mm. in the case of the fine-silver material. In annealed state, alloy No. 15 showed 29.3 kg/sq. mm. tensile strengh and 120 kg/sq. mm. Brinell hardness as compared to values of 13.45 kg/sq. mm. and 32 kg/sq. mm. respectively in the case of fine-silver. This is of especial importance where silver-plated contact points are employed. The copper alloy No. 16 with 90% copper and 10% silver has an ultimate tensile strength of 61 kg/sq. mm. and a Brinell hardness of 165 kg/sq. mm. as drawn, and 86 kg/sq. mm. Brinell when annealed.

With alternating current, the use of different materials for the contact points proved also most successful. When used for 380 volts and 5 amperes at 50 cycles, the alloys No. 15 and No. 16 showed only 2% combined loss in weight after three million switching cycles (Fig. 6), while fine-silver contacts carrying 6 A at 220 V.a.c., showed a combined loss in weight by 7.2% (Fig. 7). At the same time, the contact surfaces of the latter had been considerably affected by burning. A corresponding test run made with copper contacts had to be broken off after only 136,000 cycles, the combined loss in weight having attained 11% (Fig. 8).

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(5) Values determined by the author.

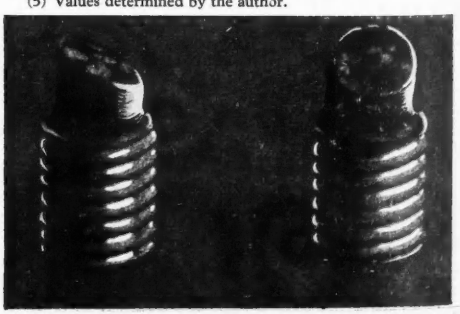


Fig. 8. Copper contacts after 136,000 switching cycles at 220 V. 6 A

A NEW LOW-TEMPERATURE TEST CHAMBER*

By Dr. Ing. Helmuth Glaser, Prague. (From *Zeitschrift für die gesamte Kälte-Industrie*, Vol. 50, No. 5-6 May-June, 1943, pp. 57-62).

The production of very low temperatures has advanced greatly during recent years. This has opened many new fields of application for low temperature technique and has raised innumerable problems in connection with the properties of several materials, and their behaviour at low temperatures, problems that, in most cases, could be solved by practical experiments only. Up to the present, several refrigeration test beds of various kinds have been developed, but none of them work at appreciably lower temperature than —60° C. [4, 5, 6][1].

Some years ago the author was entrusted with the task of designing a new kind of refrigerating test chamber that would yield essentially lower temperatures than have been available hitherto. This article indicates how the results were achieved.

Plants of a similar nature were hardly known at the time and no experience was available for guidance in selecting the most appropriate system of refrigeration. Cooling by means of solid carbon dioxide was out of the question, mainly on account of the specified low temperatures. The next investigation concerned the adaptability of an evaporation type of refrigerating machine in which a temperature below —100° C. should have been reached. This would require at least two different refrigerants, for instance, ammonia and ethane arranged in cascade. Ethane, though offering some good thermal properties, was considered unsuitable on account of its combustible and explosive qualities [3]. Besides, an intricate three or four-stage installation would have been necessary. The cooling appliance able to deal with a refrigerating capacity of several thousand calories per hour, would assume an enormous size and the dimensions of the plant would be out of proportion to the useful content of the test compartment. Also, the heat capacity of the cooler would be extremely high owing to its size and, the amount of refrigerant used would cause extended cooling periods which would be inconvenient for carrying out the tests.

Another similar process, dynamic refrigeration, has been adopted successfully in many cases. By this method cold is produced by expanding air in an expansion turbine. The cold air immediately flows through the test chamber, but must be removed again by a vacuum pump in order to maintain the back pressure in the turbine.

Fig. 1 illustrates diagrammatically the method of operation. The air leaves a compressor *a* at a pressure of a few atmospheres and proceeds to a water cooler *b* where it is cooled to a temperature almost equal to that of the surrounding atmosphere. It then enters the evaporator *c* of a multi-stage evaporation refrigerating machine *d* where it is pre-cooled to approximately —30° C., and its total content of water vapour is almost eliminated. In a subsequent expansion in turbine *f*, pressure and temperature of the air are again reduced which performs a certain amount of work and is utilized to help to drive the compressor. The air now flows through the test chamber *g* and is sucked away by the turbo-compressor *h*. Pre-cooling was done to withdraw a sufficient quantity of moisture from the air to prevent the formation of frost in the turbine. Two evaporators are required for maintaining a continuous service, and while one is working, the other must be freed from ice by thawing. Instead of drying by low temperature cooling, it may be found more convenient to reduce the moisture adequately by applying a silica-gel or similar type of air dryer. This apparatus is also required in duplicate to allow the regeneration of gelatine during running, since at this stage, the temperature of the medium entering the turbine exceeds that of the surrounding air, and the turbine has, therefore, to produce a higher temperature drop. Pressure at the turbine inlet must be increased proportionally and, as well as the usual regulating valves and bypass pipes for adjustment of pressure and temperature in the test compartment, an electric heater is often included in the installation. Some plants can be made to work with one compressor instead of the two machines *a* and *h* as shown in Fig. 1.

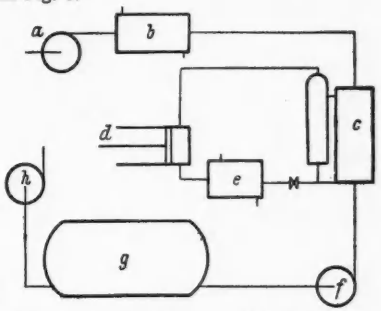


Fig. 1

The most important feature of this process is the exceptionally short time required for cooling the chamber. Temperature and pressure in the test room can easily be controlled and adjusted for a definite period. The application of the process is most profitable when very large quantities of heat, at low temperatures, are to be removed and the nature of the test involves a continuous renewal of air in the test room.

These conditions, however, do not prevail in the majority of routine tests, so that the dynamic refrigerating method entails initial and maintenance costs out of all proportion.

Searching for a more suitable system of producing cold, the throttling process, namely, the Thomson-Joule system was considered. This method was introduced into low temperature technique by Linde as early as 1895. At first sight, it appeared little promising on account of the expected high input. But the process was soon proved to be very effective for the purpose.

When expanding air by throttling, the air will be cooled to a relatively small extent and a heat transfer unit of the counter flow type must be applied, to adequately pre-cool the medium before entering the throttle valve. The arrangement of the plant is shown in Fig. 2. Air from the compressor *a*, is cooled in the water cooler *b*, and again in the counter flow system *c*. Passing the throttle point *d*, the temperature is again reduced by a definite amount to its minimum value. The

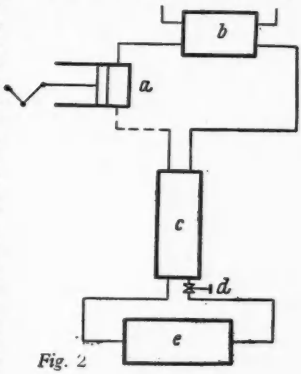


Fig. 2

*Paper read at the Refrigeration Committee of the V.D.I. Stuttgart in January, 1943.

(1) Figures in square brackets refer to the list of literature at the end of the article.

useful refrigerating capacity is now taken from the expanded medium in the heat absorber *e*, and the remaining cold is eliminated from the air, by heat transfer to the compressed air in the counter flow system, which the air then leaves at a temperature approximately equal to that of the incoming high pressure air. This process is represented by the graph Fig. 3, from which the refrigerating capacity to be obtained can easily be taken. By approximation, isothermal compression and perfect heat transfer have been assumed to take place in the counter flow tank. Point 1 represents the suction in the air line, 1-2 the isothermal compression, and 2-3 the temperature drop of the compressed medium in the counter flow device. The heat content of the air remains constant during the throttling process (line 3-4). Line 4-5 denotes the rise of temperature of air in the absorber and the stage 5-1, the heating of the air in the counter flow system, when the medium will have returned to its initial state.

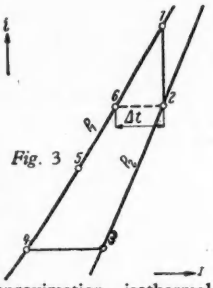


Fig. 3

The refrigerating output in calories per kg. of air is the difference between the heat content of the medium at the inlet and outlet of the heat absorber:

$$Q = i_5 - i_4 \quad .. \quad .. \quad .. \quad .. \quad (1)$$

As the quantity of heat emitted by the compressed air to the counter flow apparatus must be equal to that absorbed by the expanded air, it will be

$$i_2 - i_3 = i_1 - i_5 \quad .. \quad .. \quad .. \quad (2)$$

And the heat content of the air will remain constant during throttling so that

$$i_3 = i_4 \quad .. \quad .. \quad .. \quad .. \quad (3)$$

Hence, from equations (1) to (3):

$$Q = i_1 - i_2 \quad .. \quad .. \quad .. \quad .. \quad (4)$$

The refrigerating duty per kg of air is, therefore, just as high as the difference of the heat content of the expanded and compressed air, at the hot end of the counter flow tank. Consequently, the output is independent of the air temperature before entering the throttle valve, but is influenced by the temperature prevailing at the hot side only of the counter flow unit.

With regard to the refrigerating capacity, Fig. 3 leads to further conclusions. If Δt denotes the temperature drop occurring, when throttling the air at the final state immediately following the compression, i.e. from the point 2 to 6, then to

$$i_1 - i_2 = i_1 - i_6,$$

$$Q = c_p \Delta t \quad .. \quad .. \quad .. \quad .. \quad (5)$$

where c_p denotes the specific heat of the expanded air. The following calculations are limited to very small pressure variations. Equation (5) is therefore transformed to:

$$dQ = c_p.dt \quad .. \quad .. \quad .. \quad .. \quad (6)$$

If α_i denotes the differential Thomson-Joule effect, namely the ratio of the infinitely small temperature variation to the infinitely small pressure drop, producing the former, it will be

$$\alpha_i = \left(\frac{\delta t}{\delta p}\right)_i \quad .. \quad .. \quad .. \quad (7)$$

the index $_i$ indicating that the heat content remains constant during the throttling process [1]. Since

$$dt = \alpha_i.dp \quad .. \quad .. \quad .. \quad .. \quad (8)$$

the following term will result for the differential refrigerating output by using equation (6):

$$dQ = c_p.\alpha_i dp \quad .. \quad .. \quad .. \quad (9)$$

or by introducing the specific refrigerating capacity K. being the produced quantity of cold per kWhr.

$$K = \frac{dQ}{dN} \quad .. \quad .. \quad .. \quad .. \quad (10)$$

when dN is the small work performed by the isothermal compression of the air by the amount dp which amounts to:

$$dN = \frac{p\,v}{367000} \cdot \frac{dp}{p} \quad .. \quad .. \quad .. \quad (11)$$

Hence, the specific refrigerating output will be

$$K = 367000 \frac{c_p.\alpha_i}{p.v} \cdot p \quad .. \quad .. \quad .. \quad (12)$$

Since the product p.v, the denominator of equation (12), will depend almost exclusively on the temperature, and to a very small extent on the pressure only, the latter will materially influence the yield in specific refrigerating output, although it will be found that this influence will, in part, be compensated with high pressures exceeding c_p and α_i.

Equation (12) was computed from the tables for air by H. Hausen [1]. In curves (Fig. 4) the refrigerating capacity *K* is entered as a function of the pressure *p* (atmospheric absolute) at different absolute temperatures *T*. As will be seen the capacity *K* increases considerably with rising pressure and also with lower temperatures. The maximum specific refrigerating capacity is attained at a pressure near 160 atmos. abs.

To compare the effectiveness of the throttling process with that of other methods, the efficiency of the Carnot-cycle offers an appropriate basis. A special feature of the process is its adaptability to the production of cold at any temperature, provided the heat transfer system is of adequate capacity and the final temperature is not below that of the inversion state, when the Thomson-Joule-Effect would become zero.

Fig. 5 shows the efficiencies of the hypothetical Carnot-cycle under various conditions. The curves in heavy lines are for a cold producing temperature of −100 °C., the dotted curves for −130 °C. The values in the range of the higher pressures appear rather high and the application of the throttling process no longer seems inconsistent, particularly when considering that the efficiency of the Carnot-cycle, even of evaporation refrigerating machines of smaller capacities, will hardly exceed 30 to 40 per cent. of the temperature range under consideration. The efficiencies in Fig. 5 are ideal values which cannot be reached. They are exclusive of the losses occurring in the counter flow apparatus. Further, the isothermal compression cannot be accomplished in practice; on the contrary, an additional evaporation refrigerating machine may have to be provided for pre-cooling the air, to the requisite low temperature for entering the counter flow system.

Even neglecting these losses Fig. 5 proves that the effi-

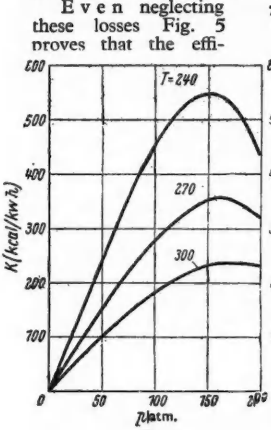


Fig. 4

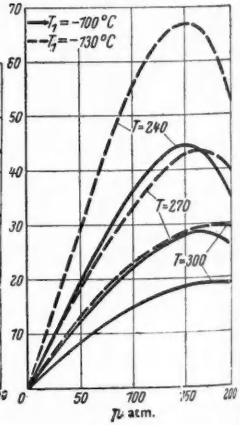


Fig. 5

ciency of the Carnot-cycle, in this instance, is far below the ideal 100 per cent. This is explained by the irreversible processes taking place during throttling and the heat transfer in the counter flow unit.

According to the first and second principal law of thermodynamics, the following relation holds for the work AL performed during the refrigeration process:

$$AL = (\Delta s_o + \Sigma \Delta s_v)\ T - Q \quad .. \quad .. \quad (13)$$

Δs_o denotes the theoretically determined variation of the entropy corresponding to the refrigerating output Q, $\Sigma \Delta s_v$ the aggregate entropy variations occasioned by irreversible processes, and T the compression temperature of the air. Δs_o is determined by the following expression:

$$\Delta s_o = \int_0^Q \frac{dQ}{T_1} \quad .. \quad .. \quad .. \quad .. \quad (14)$$

T_1 being the temperature prevailing during the production of the cold quantity dQ. The increase of entropy during throttling is

$$\Delta s_{vd} = \int_{P2}^{P1} \left(\frac{\delta s}{\delta p}\right)_i dp \quad .. \quad .. \quad .. \quad (15)$$

when p_1 and p_2 are the pressures after and before throttling respectively, the heat content remains constant during the process, as indicated by the index i. Since the specific heat of highly compressed air is generally higher than that of air under minor pressure, temperature difference will exist in the heat transfer apparatus which, with an ideal counter current system, will gradually rise from zero at the hot end. This again will involve a loss of entropy [2]:

$$\Delta s_{vg} = \int_0^{Qg} \left(\frac{1}{T'} - \frac{1}{T''}\right) dQ_g \quad .. \quad .. \quad (16)$$

when Qg denotes the amount of heat to be transferred in the counter flow unit, T″ and T′ the temperatures of the compressed and expanded air respectively, prevailing at the point of transfer of heat quantity dQg.

The values of the integrals in equations (14) to (16) can be taken conveniently from the T-s diagram, which also indicates the proportion of the loss of work to the total work performed. Fig. 6 shows the air cycle in heavy lines, the points 1-5 corresponding to those in Fig. 3. Δs_o is represented by the horizontal distance

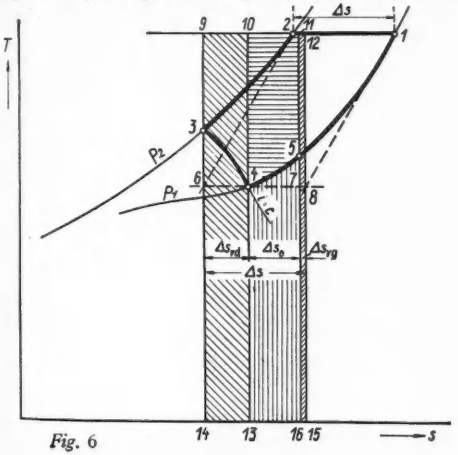


Fig. 6

between points 4 and 5, and s_{vd} by that between 3 and 4. If a parallel line is drawn through 1 to the straight line connecting 2 with 6, the distance between 6 and 8 indicates the total change of entropy Δs, and the distance 7-8 is the loss of entropy Δs_{sg}. The area 4-5-16-13 represents the refrigeration output and area 4-10-11-5 the theoretically required minimum work $AL_o = T.\Delta s_o - Q$. Areas 9-10-13-14 and 11-12-15-16 respectively, indicate the unproductive work for the throttling process and for covering the transfer loss in the counter flow unit. The friction losses in the pipe system have been neglected.

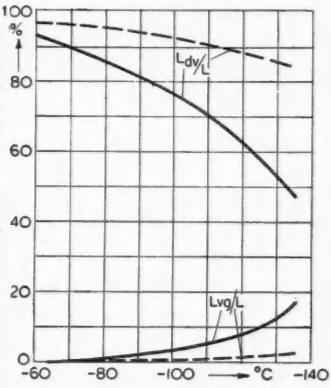
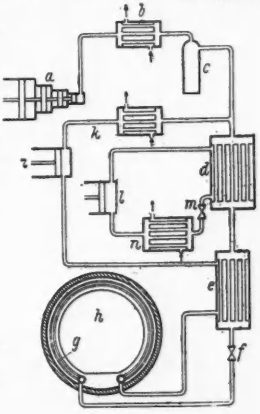


Fig. 7

Fig. 7 shows the percentage ratio of the two amounts of extra work to the total work (L) to be performed as a function of the mean temperature prevailing during refrigeration. The top curves refer to the loss of work due to throttling (L_{vd}), the bottom curves to the loss by transfer (L_{vg}). The following conditions have, therefore, been assumed: final compression 200 atm., isothermal compression temperature —30° C., pressure at the end of the expanding process 50 and 1 atm., respectively. It appears that the highest losses occur during expansion, which, however, are greatly reduced at lower temperatures and still more when the counter pressure is increased, say from 1 to 50 atm. In the latter case the transfer loss in the counter flow unit will increase to a certain extent, but its share in the total work is small at either pressure.

Two important conditions appear decisive for a profit yielding application of refrigeration by throttling, owing to the influence on the Carnot efficiency of air pressure and temperature at the inlet of the counter flow system (Fig. 5). Firstly, the process must be carried out in the high-pressure range as a closed cycle, and secondly, the air should be pre-cooled as effectively as possible before it enters the counter flow system.

This leads to a programme of operations as indicated in Fig. 8. The air, after passing a single-stage high-pressure compressor, flows in a closed cycle through the following units in this order: Evaporator, counter flow system, throttle valve, heat absorber. Then it returns through the counter flow apparatus to the suction side of the compressor. A small priming compressor is



a	Auxiliary compressor
b, k	Water coolers
c	Dry flask
d	Evaporator
e	Counter flow unit
f, m	Throttle valves
g	Air cooler
h	Test chamber
i	Air compressor
l	Refrigerating machine
n	Condenser

Fig. 8

provided for the initial filling of the system and making good any leakages.

The design of the plant appears attractively simple and clear. Compressor and counter flow unit become small, owing to the high working pressures and to the high heat transfer co-efficients. The cooling system is of appropriate design, light in weight and of low heat capacity and can be accommodated inside the test chamber. The initial cost of the installation compares very favourably with those of any other cooling method and the air offers the most ideal refrigerating medium.

All these advantages together ultimately decided in favour of the throttling process. The somewhat higher running cost could be accepted without hesitation, because the unavoidable intervals occasioned by waiting, etc., connected with tests of this nature are many times longer than the actual working periods. The higher inherent inertia of the plant, in contrast with that of the dynamic refrigeration method, could not be considered as a drawback, having in mind the nature of the tests to be undertaken.

Before construction of the plant the most favourable values of the suction pressure and final compression had to be determined. In addition to the conditions previously discussed, practical considerations led to the adoption of the two pressures of 50 and 200 atm. The latter was considered the maximum admissible pressure. 50 atm. appears to be rather on the low side with regard to the data in Figs. 5 and 6. However, an increase of the suction pressure would involve a higher weight of the circulating air, since the refrigerating capacity available per kg of air, would become less with a reduced pressure drop. Also, the temperature drop at disposal for the heat transfer in the counter flow system would be reduced, whereas the amount of heat to be transferred would increase, owing to the extra amount of circulating air. Both conditions would lead to a very much larger counter flow unit which, due to its higher heat capacity, would involve an undesirable extension of the cooling period of the plant. Further, the outer wall thickness of the heat transfer tank would have to be increased, because of the medium-pressure air flows through its outer jacket space.

The selection of the pre-cooling temperature was facilitated by local conditions. An ammonia refrigerating machine operating with calcium chloride brine, belonging to another plant, was available, close to the site of the new test chamber. As the cooling capacity required for the pre-cooling of the high-pressure air was relatively low, it could be taken from the brine cooler of the ammonia plant without impairing its function.

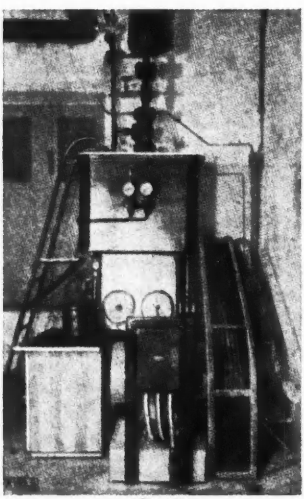


Fig. 9

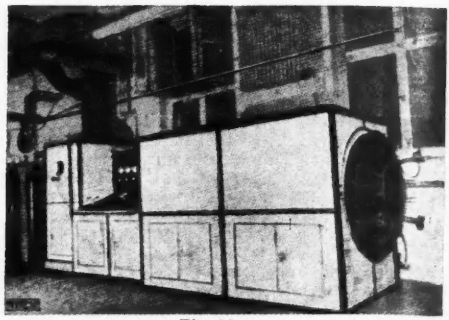


Fig. 10

Figs. 9 to 13 give details of the completed installation. The vertical two-cylinder air compressor (Fig. 9) was built in the machine works of the Linde concern. The compressor is belt-driven by a squirrel-cage three-phase motor. An oil separator in the high-pressure pipe line, mounted behind the compressor, arrests any oil floating in the line. As no moisture will be present in the system and consequently no formation of ice could take place in the heat transfer unit, it was not considered necessary to provide a dry flask for absorbing the water vapour. Solely for the drying of the additional air introduced into the high-pressure cycle, a calcium chloride flask is inserted at *c* (Fig. 8). A battery of compressed air cylinders with the requisite valves is connected to the high-pressure pipe line to ensure quick starting. Several safety valves, distributed along the cycle, protect the system against excessive pressure.

Fig. 10 is a complete view of the test chamber, the regulating section and the counter flow portion. The top parts of the heat transfer unit, together with the pipes connecting it with the pre-cooler and compressor are insulated with cork, to keep the suction temperature of the compressor as low as possible and to save motor power. The bottom part of the counter-flow tank and the cold pipes running below the regulating desk, are insulated with slag wool, so as not to impair accessibility of this section in case of leakage. The instruments for the pressure and temperature control of the entire plant are fixed at the rear of the switch desk.

Fig. 11 shows a cross section of the horizontal type refrigerating chamber. The two removable end covers permit easy access to the interior. The air cooler is mounted in the outer annular space. The desired uniform temperature inside the test room is attained

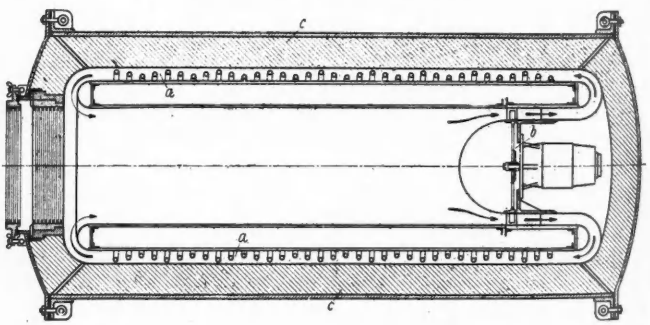


Fig. 11

by forced air circulation produced by a high efficiency axial blower, fixed to one of the front sides of the chamber, and draws air from the test compartment proper, to force it through the cooler in such a way, that the air flow strikes the pipes in cross currents, thus producing an effective heat transfer.

It has been decided also to place the blower motor inside the chamber, though it will be subiected there to the influence of the low-temperature atmosphere Extra heat will have to be eliminated; this heat may be produced not only by the useful work of the motor, but also by electrical losses. Many difficulties were removed by avoiding an extension of the motor shaft through the cover of the chamber which would have caused additional heat losses by conduction along the shaft.

The rate of cooling the chamber is in the first place dependent on its heat capacity. The latter is reduced to a great extent by arranging the insulation on the inner surfaces of the wall, the great mass of which need not to be cooled to the low inside temperature. For the same reason, a special insulation material was applied in flat sheets to the cylindrical section of the chamber, whereas a kind of creased insulation was used for the covers to facilitate accessibility to the many wall bushings leading outside.

One of the lids carries all the bushings, the majority of which are for the medium pressure pipes leading to the cooler. The other cover is provided with a large circular aperture for assembly purposes. This can be fitted, if desired, with an inspection window. Fig. 12 shows a view through this opening to the interior of the chamber.

The operation of the plant is exceptionally simple. Only the smooth running of the machines during test has to be controlled. Equally simple is the adjustment of the desired temperature. By regulating the throttle valve, the pressure ratio and the pressure difference of the air expansion can be varied at will. As the refrigerating capacity is at first approximation proportional to the pressure difference, the process yields a power regulation perfectly free from inherent inertia and a smooth stepless adjustment of the output between zero and full rated load. Also the input of the compressor is reduced corresponding to the decrease in the pressure ratio

The plant has been working since 1937. Setting aside the occurrence of some leakages at the beginning

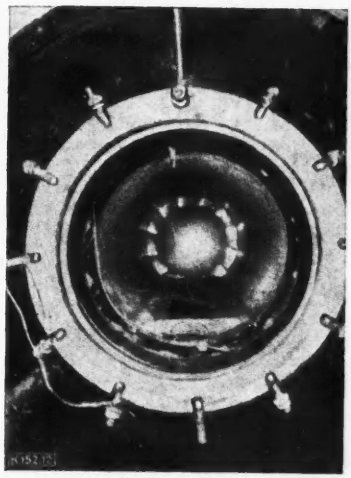


Fig. 12

no serious difficulties were encountered either at the initial setting to work or since then. The specified low temperature was easily attained and even considerably lower temperatures down to —115 °C, have been recorded in many cases.

The advantages of the plant may be summarized as follows : low first costs, use of air as cooling medium, easy manipulation, single-stage operation, and smooth power regulation with no inherent inertia.

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HOT AIR AND COMBUSTION TURBINES IN THE STEAM POWER PLANT

By D. Ing. F. Nistler. (From *Feuerungstechnik*, Vol. 30, No. 9, 15th September, 1942, pp. 207-211.)

This article is intended to prove that the generating capacity of steam electric plants can be increased by air preheating under increased pressure, instead of at atmospheric pressure as usual. In its simplest form, this proposal can be realised by using the exhaust of a hot air engine as combustion air for a boiler. With condensing operation, a system of this kind will effect a small increase in plant efficiency; while with back pressure operation, as used in district heating plants, a considerable increase in by-product power will result.

A hot air turbine arrangement of this kind is shown in Fig. 1. Compressed air supplied by the compressor (1) is heated in the independently fired compressed air heater (2) and then admitted to the hot air turbine (3). The exhaust of the latter is passed to the boiler plant, where it serves as combustion air. In order to compute the increase in efficiency obtainable with this arrangement, the compressor efficiency may be assumed as 84.6%, the turbine efficiency as 88.4%, and that of the air heater as 75%. Based on an air condition of 4.5 atm. (63.9 lb./sq. in.) and 550° C. (1,022° F.) at the turbine throttle, the air conditions at the compressor discharge will be 5 atm. (71 lb./sq. in.) and 208° C. (406° F.), allowing for a pressure drop of 0.5 atm. (7.1 lb./sq. in.) in the air preheater. Considering the power consumption of the compressor and assuming 1% mechanical and 4% electrical loss, the output at the generator terminals is shown to amount to the equivalent of 17.64 kcal./cu. m. of the air at N.P.T. (1.98 B.T.U./cu. ft. at N.P.T.). The efficiency of this hot air plant is estimated at no more than 12.14%. It is further assumed that on its passage from the turbine to the boiler, the exhaust air may suffer a drop in temperature from 303 °C. (577° F.) to 280 °C. (536 °F.).

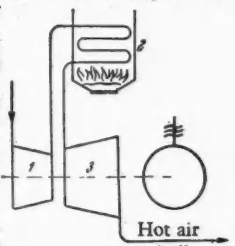


Fig. 1. Hot air turbine for preheating combustion air in a steam power plant.

In a condensing plant, the incorporation of hot air turbine plant will lead to an increase in plant efficiency from 24 to 24.32%, which is equivalent to an increase in capacity by 1.33%. This improvement is, of course, much too small to justify the installation of the hot air turbine plant. But this computation goes to show that a thermal coupling of two thermal power plants can result in a combined thermal efficiency which is in excess of the individual thermal efficiencies of the component parts.

Much better prospects for the application of this operating principle exist in the case of back pressure plants. Without the employment of a hot air turbine, the heat balance of a district heating plant with by-product power generation may be assumed to be thus:

Electric output at generator terminals	9.2%
Heat to heating lines	63.9%
Losses	26.9%
	100.0%

Compared to this, the incorporation of a hot air turbine plant will increase the electric output to 10.59% and will reduce the heat delivery to 59.32%. This means that the electric output is increased by 15.1%, while the heat delivery is reduced by only 7.7%. In addition to this, the installation of the hot air turbine plant serves as a source of emergency power.

In view of the low thermal efficiency of the hot air turbine, the use of a combustion turbine of the constant pressure type will be preferred in actual practice. In its simplest form, a turbine installation of this type comprises the constant pressure combustion chamber D (Fig. 2), the centrifugal air compressor V, and the combustion turbine T. In order to limit the temperature of the combustion products at the gas turbine inlet to 550° C. (1,022° F.), a high excess air factor must be used which, in the case considered, reduces the oxygen content of the combustion "air" to 17.23%. But this should not cause any operating difficulties.

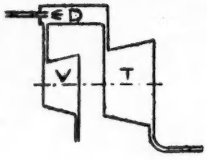


Fig. 2. Constant pressure turbine (Brown-Boveri type).

For pulverised fuel firing, the combustion air temperature of 280–290° C. (537–554° F.) is somewhat low, but it is still sufficient. For stoker firing, this temperature range appears as rather high; but this is counteracted by the low oxygen content. Furthermore, in the case of trouble, air conditioning by humidification of the air can be resorted to.

In the constant pressure combustion turbine arrangement outlined in Fig. 3, cooling of the gases is effected in a surface cooler, compressed air being the coolant. The cool air discharged from this cooler is subsequently expanded in the hot air turbine G. An arrangement of this kind is also applicable to the firing of solid fuel, as powdered coal, etc. However, this will necessitate cleaning of the gases prior to their admission to the turbine by means of dust separators. But should the ash content of the gases still prove harmful to the turbine blades, the turbine G could be dispensed with altogether by expanding the gases through jet nozzles arranged in the boiler uptake, hereby creating the required amount of induced draught. Similarly, the expanding gas could be used to decrease the back pressure of turbine T by ejector action.

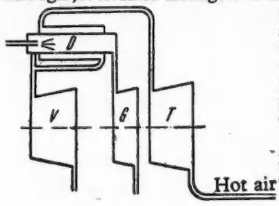


Fig. 3. Constant pressure turbine with combustion chamber cooling by compressed air.

PROGRESS IN HEAT TREATMENT OF ALLOY CAST IRON

By J. S. VANICK, International Nickel Co., New York. (From *The Foundry*, Vol. 71, No. 7, July, 1943, pp. 90-92, and 178-179 and August, 1943, pp. 96-97 and 176-178.)

THE slow progress made in the heat treatment of cast iron is due to the presence of several important physical and economic factors which must be overcome before further progress can be made. These obstacles barring the way to large scale employment of heat treatment are: (1) Need to exclude all but simple, symmetrical shapes; (2) Machinability; (3) Distortion, prohibitive cost (except for large volume of parts to absorb cost); (5) Ability to make high strength parts "as cast" hereby avoiding difficulties with distortion or lack of machinability.

As heat treatment adds an appreciable increment of cost to the casting, it is desirable to avoid the hazards of indifferent response such as may occur in the poorer grades of cast iron. This can be done by limiting the application of heat treatment to those irons whose composition and care in production justify the additional cost and attention required by heat treatment.

It is important that the heat treater should know and control by close specification the actual composition of the material he is handling if best results are to be obtained. Plain cast irons, for instance, can be processed more rapidly through a softening anneal than alloyed varieties; but the latter may be subjected to somewhat higher temperatures during stress relief annealing with a much smaller risk of impairing mechanical properties. Furthermore, in the quenching treatment, it is important to raise the temperature sufficiently high above the critical range in order to dissolve all constituents essential to the hardening treatment. Some elements lower the critical range, while others, as, e.g., silicon, raise it. Thus, a heat treatment suitable for a low silicon composition may fail if the castings made to identical strength or similar physical property specifications should happen to be made with a high silicon material.

Contrary to the popular belief that heat treatment is applied only to strengthen or harden a casting, there are many important objectives for which metals are heat treated. Thus, heat treatment may not only be used to "surface harden" a soft iron, but—what is more astonishing—to "surface soften" a hard iron. Stress relief annealing is defined as the process of reducing internal residual stresses in a casting by heating it to a temperature (usually below the transformation range) and holding for a proper time at that temperature. Stresses are removed more quickly and completely the higher the temperature or the longer the time of heating. However, unless the metal is heated high enough to lower its elastic properties to zero, complete stress relief cannot take place, and the elastic return of the metal will again restore some of the internal stresses. Actually, the amount of plastic deformation required to produce stress relief is very small, being of the order of 0.001 in. per in.

Present practice is to relieve internal stresses in castings by heating to 800–1,050° F., holding at temperature for a time of one hour per in. of section, and then cooling slowly in the furnace. Alloyed irons may generally be heated to higher temperatures (approaching

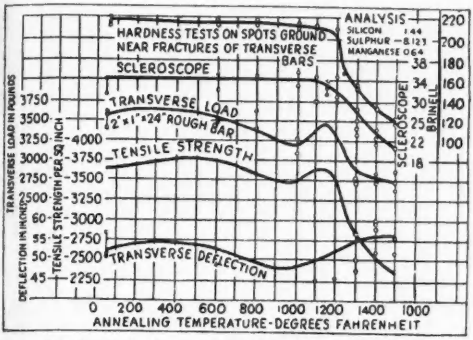


Fig. 1. Results obtained on cast irons annealed at various temperatures according to MacPherran and Harper.

1,200° F.), and may be held for shorter periods of time. Castings which are hard and unmachinable because of the presence of " chill " may have to be heated to as much as 1,700 to 1,800° F. Assuming that carbide stabilising elements such as chromium, sulphur, molybdenum, vanadium, etc., are not present in excess, heating at 1,700 to 1,800° F. for one to three hours per in. of section, will break down the chill and restore machinability. The cooling rate may be timed to either retain normal strength and hardness or to obtain a soft, weakened iron. But these heat treatments are mainly used as reclamation measures in cases where the composition is out of balance in terms of " susceptibility to chill " and are rarely required in regular foundry practice.

Annealing may be used to soften castings already grey throughout in order to facilitate rapid machining. The usual results are a general softening of the iron accompanied by a deterioration of the mechanical properties. The rapid softening and weakening of plain cast iron when heated above 1,200° F. is illustrated by the graph reproduced in Fig. 1. Careful control is essential in order to limit this reduction in physical properties. The usual procedure employed in annealing is to heat the casting above the upper critical range, holding at temperature for definite time intervals, and then cooling at a predetermined rate to room temperature. Usually, 1,500 to 1,600° F. is high enough for the annealing of plain irons. The time at temperature need not exceed one hour per in. of section. As Fig. 1 shows, longer periods of heating at temperatures above the critical point may produce appreciable changes. Once the casting has been uniformly heated at the annealing temperature, the rate of cooling through and immediately below this range will establish the final combined carbon content, the amount of softening and the degree of deterioration in physical properties (Fig. 2).

Hardness increases of 150 to 300 Brinell units can be obtained by heat treatment, the quenching temperatures used on most irons ranging from 1,450 to 1,600° F. While oil is most commonly used as quenching medium, water or air are also employed to a limited extent. The higher the temperature and the greater the amount of carbon in solution at the quench, the higher are the hardnesses obtainable. A small amount of distortion occurs on quenching, and sufficient allowance must be made for this in leaving stock for finish grinding. Alloys are known to retard the progress of transformation on cooling, so that their presence may lead to hardening by air cooling. Experiments have shown that the presence of appropriate amounts of nickel, manganese, chromium and molybdenum reduces the rate of transformation to such an extent that after cooling in the mould or in the air, hardness will approach that produced in unalloyed iron by quenching in oil or water.

When casting shapes are too complicated and irregular, or shop processes prevent the application of the more drastic liquid quenching, air-cooling may be applied to harden correctly alloyed castings. Usually several per cent. of alloying constituents should be present, in proper balance, thin-sectioned castings requiring considerably less alloying than thick sections. In some cases, the air-cooling of thin castings provides a degree of control which may not be obtainable in the mould, thus producing greater uniformity in the final product.

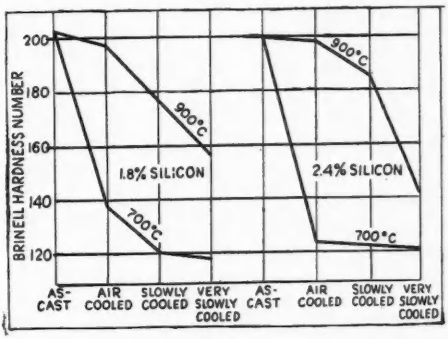


Fig. 2. Effect of rate of cooling on Brinell hardness according to A. A. Timmins. Bars of 1.2-in. diameter. Slowly cooled bar was at rate of 6 deg. F. per min. Very slowly cooled bar was at rate of 2 deg. F. per min.

EFFECT OF GRAPHITE PARTICLE SIZE IN THE INOCULATION OF GREY CAST IRON

By H. R. DAHLBERG. (From *The Foundry*, Vol. 71, No. 8, August, 1943, pp. 125-130 and 146.)

OFFERING, as it does, a fairly reliable method of controlling the physical properties of the material, the inoculation of grey cast iron has become a subject of increasing interest to foundrymen. The control of these physical properties has been considered due to the size and distribution of the graphite flakes in the material. In most cases the addition of expensive elements and alloys, such as ferrosilicon, zirconium, silicide, calcium silicide, nickel, and molybdenum, etc., is resorted to decrease carbide stability, and thus to produce precipitation of carbon from solution to form the graphite. Some investigators have, however, obtained good results with the use of graphite on the inoculant. In view of this, an investigation was made in the belief that the contact area of the inoculant with the molten metal is important and may possibly explain the mechanism of graphitisation for which no conclusive explanation has yet been forthcoming.

While many investigators have used inoculants in such amounts that the change in the physical properties of the material is bound to be due to the variation in chemical composition, these changes in the physical properties still persist when the chemical composition is kept constant. With this point in view, the less apparent factor of the particle size of the inoculant is discussed in this paper. Several investigators have shown that superheating improves the properties of certain irons, usually of a high total carbon percentage combined with the prescence of nickel, molybdenum, or chromium. On the other hand,

the properties of low carbon irons are not improved in this way, being often impaired by superheating. These investigations have led to the establishment of several controversial theories on the graphitisation of cast iron.

As Timmons and Crosby* have shown that strengths are considerably decreased when pouring high test iron at temperatures below 2,650° F., this temperature was employed throughout the investigation under review. Three heats of 250 lb. each were cast from metal previously prepared from a cupola heat, its analysis being : 3.31% C., 1.8% Si., 0.46% Mn., 0.062% S. and 0.173% P. The total carbon content of the heats was decreased by the addition of steel scrap, while the desired silicon content was obtained by the addition of silvery pig iron. The core sand used for the baked moulds of the transverse test bars and chill test bars was of the following composition by volume : 48 parts silica sand, 1 part linseed oil and 2 parts water. After baking at 425° F. for four hours, the mixture exhibited a permeability of 85 to 90. Melting was carried out in a Detroit indirect-arc rocking furnace.

The metal was tapped into a 35 lb. hand ladle, the inoculant being added to the stream. A tungsten-graphite thermo-couple was used to measure the temperature at the time of inoculation, pouring being done at 2,650° F. The time between inoculation and pouring was also recorded. As the subjoined table shows, the temperature at inoculation could not be kept constant, and without doubt this temperature variation has affected the results obtained.

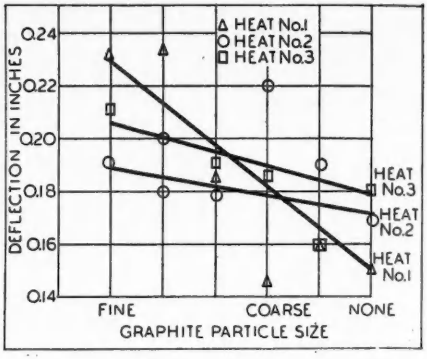


Fig. 2

Association. The microstructure of each bar was checked, and its average hardness ascertained on the polished specimen. Commercial Mexican graphite served as inoculant, the sizes used being 30 mesh, 8 mesh, $\frac{1}{8}$th in. cubes, $\frac{1}{4}$-in. cubes and $\frac{1}{2}$-in. cubes. Only twelve grams of each size were used for inoculating 35 lbs. of iron, so as to show that it is the particle size of the inoculant rather than the change in chemical composition which causes the changes in physical properties and structure of the iron.

TABLE.

Test Bar No.	Graphite Size.	Temp. at inoculation °F.	Temp. at pouring °F.	Time Diff. hr. min.	Total Carbon. %	Graphitic Carbon. %	Combined Carbon. %	Silicon. %	Transverse Strength. lb.	Deflection. Inches.
HEAT No. 1.										
11	None	—	2680	—	2.64	0.11	2.53	1.52	2400	0.15
12	30 mesh	2750	2660	1 32	2.65	1.40	1.25	1.49	3150	0.23
13	8 mesh	2690	2660	1 0	2.66	1.35	1.31	1.53	3040	0.235
14	$\frac{1}{8}$ cubes	2710	2652	1 13	2.64	1.20	1.44	1.57	2925	0.185
15	$\frac{1}{4}$ cubes	2780	2660	1 46	2.66	0.71	1.95	1.56	2535	0.145
16	$\frac{1}{2}$ cubes	2870	2670	2 23	2.64	0.70	1.94	1.58	2610	0.160
HEAT No. 2.										
21	None	—	2660	—	2.62	1.83	0.79	2.27	2550	0.170
22	30 mesh	2850	2660	2 44	2.62	1.72	0.90	2.22	2650	0.190
23	8 mesh	2730	2652	2 8	2.64	1.69	0.95	2.19	2535	0.180
24	$\frac{1}{8}$ cubes	2830	2652	2 56	2.67	1.30	1.37	2.25	2800	0.180
25	$\frac{1}{4}$ cubes	2740	2660	2 14	2.63	1.70	0.93	2.21	2800	0.220
26	$\frac{1}{2}$ cubes	2840	2642	2 56	2.65	1.65	1.00	2.18	2840	0.190
HEAT No. 3.										
31	None	—	2660	—	2.64	1.91	0.73	3.04	2400	0.180
32	30 mesh	2780	2598	2 12	2.64	1.90	0.74	3.05	2800	0.210
33	8 mesh	2890	2660	3 7	2.64	1.85	0.79	3.07	2750	0.200
34	$\frac{1}{8}$ cubes	2940	2660	4 31	2.66	1.83	0.83	3.02	2435	0.190
35	$\frac{1}{4}$ cunes	2880	2660	2 21	2.62	1.87	0.75	3.11	2460	0.185
36	$\frac{1}{2}$ cubes	2770	2660	1 47	2.65	1.88	0.77	3.04	2450	0.160

The transverse and deflection tests were made in accordance with the standard procedure given in the Cast Metals Handbook of the American Foundrymen's

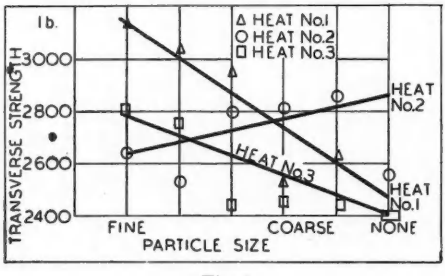


Fig. 1

The influence of the particle size of the graphite upon transverse strength and deflection in iron with 1.49–1.58 Si percentage (Heat No. 1) is shown in Figs. 1 and 2. The tabulated data also show that with

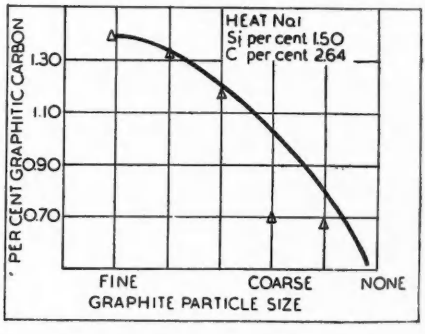


Fig. 3

* G. A. Timmons and V. A. Crosby, " Effect of pouring temperature on the strength and microstructure of grey cast iron," *Trans. Am. Foundrymen's Assoc.*, Vol. 49, p. 225.

Fig. 2

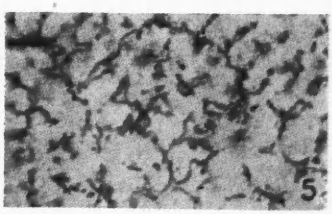


Fig. 5

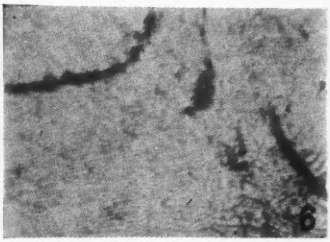


Fig. 6

low silicon irons, the particle size of the inoculent has a pronounced effect upon the graphitisation produced; and this is even more evident in the graphic representation given in Fig. 3. With more than 2% silicon present, graphitisation is probably due to the silicon rather than to the small quantity of graphite used. The effect of particle size upon the depth of chill is exemplified by Fig. 4, which refers to specimens poured from heat No. 1. Here the material with the 8-mesh graphite seems to offer the greatest reduction in chill. But this did not apply to heat No. 3, where the coarser particles produced the greatest reduction in chill. Obviously, the amount of graphite employed was too small to produce a large enough reduction in the depth of chill.

Equilibrium conditions seldom obtain in melting grey iron; and it is probable that this condition of unequilibrium is accentuated by inoculation with graphite. Specimen 12, shown in Fig. 5, probably solidified in the stable iron-graphite system; and the presence of fine graphite flakes around the primary austenite indicates that the graphite has come out of solution while cooling between the liquidus and eutectic temperatures. The fine flakes are probably due to undercooling. In the same specimen magnified 1,000 dia., the graphite flakes are seen to be surrounded by pearlite (Fig. 6). Had the iron solidified in the meta-stable system, these flakes would probably have been surrounded by ferrite, owing to the decomposition of cementite. Thus evidence points to the solidification of the iron in the stable iron-graphite system.

From these data, it may be concluded that in the inoculation of low-carbon, low-silicon irons, the graphite particle size has a decided effect on the transverse strength and deflection properties of the material. But this effect disappears when the silicon content is increased. Eight-mesh graphite seems to cause the greatest reduction in the depth of chill, but a greater amount of inoculant may perhaps be necessary. Finally, the inoculation with graphite causes solidification of the iron in the stable iron-graphite system rather than in the meta-stable iron-carbon system.

BAKELITE BOARD AS A SOURCE OF CORROSION.

By H. L. HALSTRØM, Technical Department of the Copenhagen Telephone Co. (From *Elektroteknik* (*Ingenioren*). Copenhagen, Vol. 1943, No. 64, 18th September, 1943, pp. E. 129 - E. 130.)

WHILE bakelite is generally considered to be a completely stable material, it can yet be the cause of corrosion of metal under certain conditions. Cases of this kind have for some time been experienced in a central exchange of the Copenhagen Telephone Company. As similar troubles are known to have occurred in other countries, an explanation of this phenomenon will be of interest.

The relay which was received for investigation was of the so-called flat type (Fig. 1), having a core with very flat cross section. The leaf springs of the relay are divided into two sets lying on the sides of the solenoid. The coil itself is wound on a core of bakelised cardboard with two flanges. The flange which is farthest away from the armature is also used for supporting the topmost spring, which latter is equipped with a projection resting on the flange. This projection was found to be considerably corroded on one of the spring sets (Fig. 2), while there was nothing visible to the naked eye on the projection of the other top leaf. However, under the microscope incipient corrosion could be detected. Considering the situation, there was no doubt that the corrosion was caused by the bakelite flange, and that it was due to electrolysis. This was corroborated by the fact that the affected spring was at a potential of 48 V against the iron core, the latter being connected to the earthed positive terminal of the battery. The other spring with the microscopically corroded spot was under voltage only for short periods at a time. This points to the possibility that electrolysis is due to the fact that the layer of paper extending from the relay core to the resting point of the leaf spring can absorb very small amounts of moisture, particularly in the centre of the flange where the bakelite may be assumed to be of the least hardness—that is to say, where it has transformed least from the soluble A — modification into the insoluble stable C—modification. Corrosion will, in all likelihood, be avoided if in the place of the bakelised board, a die cast flange of bakelite S or S*v* is used which consists of a phenol-cresol resin with wood dust as filler. In this way there is no continuous layer of cellulose fibre as in the case of the laminated board; there are only wood-dust particles surrounded by an insulating film of bakelite resin.

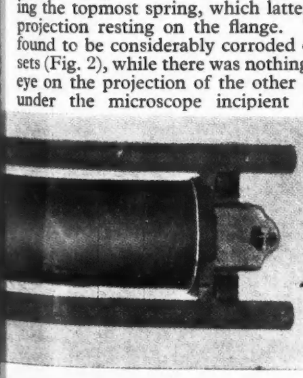


Fig. 1

A perusal of the pertinent literature shows that a completely analogous case has been reported by A. Spitzer,* who refers to the corrosion of relays and line-finders. In this case also, the replacement of bakelite board

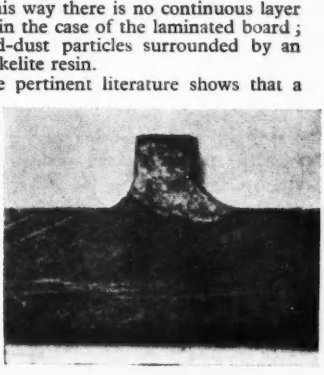


Fig. 2.

* A Spitzer, "Investigations on the corrosive action of laminated bakelite sheet," *Bl. Nachrichten Technik*, Vol. 17 1940, p. 269.

flanges by others of moulded bakelite 0 (phenol resin with wood-dust filler) had also prevented further cases of corrosion. It was ascertained by Spitzer in a series of investigations that corrosion is caused by the electrolysis of bakelite board under the joint influence of heat and moisture. When testing a sample of laminated bakelite sheet subjected to a d.c. potential in a hot and humid room for some length of time, the insulating properties of the piece were observed to decrease markedly in the proximity of the negative terminal, while they increased near the positive terminal. Spitzer concludes that by suitable surface treatment, the corrosive effect will probably be largely suppressed. Finally, it must be noted that it is possible that it is not the bakelite itself, but rather the cellulose of the cardboard which should be held responsible, since the latter is subject to electrolysis. This view is supported by the results obtained with the replacement of bakelite cardboard by moulded bakelite.

GAS TURBINE WITH WASTE HEAT UTILIZATION BY AIR PRE-HEATING.

by DIPL.-ING. H. PFENNINGER. (From *Die Wärme*, Vol. 66, No. 17, August, 1943, pp. 200-201).

WITH present day designs of single-stage gas turbines operating with a temperature of 600 deg. C. at the turbine inlet, a thermal efficiency of about 19 per cent is obtained, if no pre-heater is provided and if no inter-stage cooling of the air compressor is resorted to. In view of such a low thermal efficiency, the employment of gas turbines can be justified only in special fields, that is, in cases where small space requirements, low weight, ease of operation, and low capital cost are more important than low fuel consumption. In its simplest form, the gas turbine will also be competitive where the supply of water is practically impossible or excessively costly.

However, the heat exchanger furnishes a means of improving thermal efficiency, and if such a heat exchanger were only made large enough, it would (theoretically at least) be possible to equal or even excel the thermal efficiency of an equivalent steam power plant. The question therefore arises, whether a heat exchanger of such a large size could be economically feasible. The interrelationship between the thermal efficiency of a gas turbine plant operating with an admission gas temperature of 600 deg. C. and the size of the air pre-heater is charted in Fig. 1a.

Referring to this graph, it is seen that to reach a thermal efficiency of 30 per cent, a specific heat exchanger surface of 2.5 sq.m. per kW is required. Since a heat exchanger of this type will operate in a temperature range of 160 to 390 deg. C., its tubing need not be made of high temperature resistant material. Its cost need not therefore be as high as that of a Cowper stove. According to the experiences of the Brown-Boveri Co., the cost of heat exchangers for gas turbine plants can be taken to range from 20 to 30 RM per sq.m. of surface.

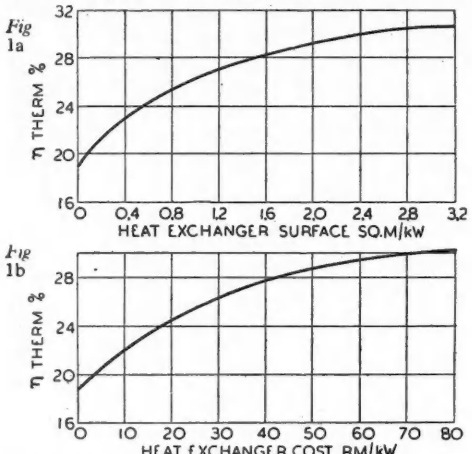


Fig. 1a. Thermal efficiency versus heat exchanger surface.
Fig. 1b. Thermal efficiency versus heat exchanger capital cost.

Assuming a cost of 30 RM per sq.m., the relationship between thermal efficiency and heat exchanger cost will be that charted in Fig. 1b. The cost of fuel for 6,000 hr. of operation per year *versus* thermal efficiency is given by curve (1) charted in the upper part of Fig. 2. In order to make these data comparable to

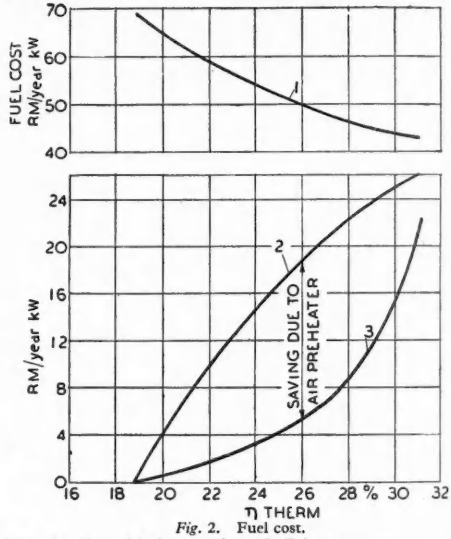


Fig. 2. Fuel cost.

Curve 1. Cost of fuel versus thermal efficiency.
Curve 2. Saving in fuel cost due to installation of air pre-heater.
Curve 3. Total annual cost of air pre-heater operation.

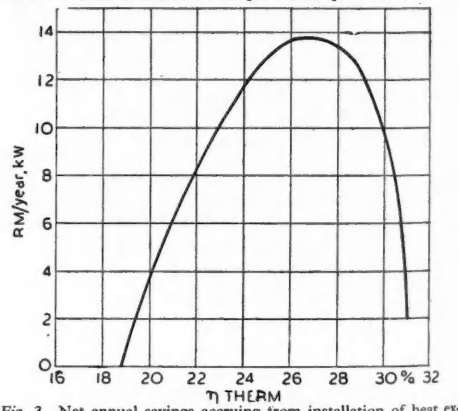


Fig. 3. Net annual savings accruing from installation of heat exchanger (air pre-heater).

those given by Martin,* they have been based upon a price of 0.25 RPf per 1,000 Kcal of blast furnace gas.

The saving in fuel cost resulting from the employment of a heat exchanger is given by curve (2) in Fig. 2, while the total annual cost of operation of the heat exchanger is represented by curve (3) which is based on an annual charge of 20 per cent of the capital cost, to cover interest, depreciation, and maintenance. On this basis, the net saving accruing from the heat exchanger installation is given in Fig. 3. This graph indicates that minimum charges are registered with a thermal efficiency of 26 to 27 per cent. If the capital cost of the turbine plant excl. heat exchanger is taken as 100 RM (according to Martin) the relationship between thermal efficiency and cost of plant including heat exchanger will be given by the curve shown in Fig. 4.

*See "THE ENGINEERS' DIGEST," Vol. IV., No. 11, November, 1943.

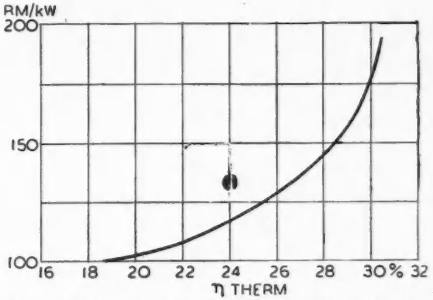


Fig. 4. Capital cost of gas turbine plant versus thermal efficiency. (● indicates the cost of steam plant according to Martin).

GLASS FIBRES—A NEW ENGINEERING MATERIAL

(From *The Iron Age*, Vol. 152, No. 19, 4th November, 1943, pp. 60-61).

THE Owens-Corning Fiberglas Corp., Toledo, U.S.A., has announced the availability of seven basic types of glass fibres as raw materials for use with other fibres and with plastics and cements, and for use in various types of industrial and chemical process equipment.

It is hoped that availability of the fibres will lead manufacturers to experiment with them, both to meet current urgent needs and with a view to post-war products and markets.

Fibreglas fibres are now being used in combination with plastics where they serve as reinforcement for light-weight, high-strength structural parts for aircraft.* The Fibreglas plastic parts can be moulded at low pressures, reducing fabrication costs and man hours. Experience indicates the adaptability of the fibres to similar use as reinforcement for certain cements and plaster-like materials where their high tensile strength may give improved physical properties to the resulting product.

It is also believed that the high tensile strength and non-stretching and non-shrinking characteristics of Fibreglas fibres will contribute new and valuable properties to other fibre and textile materials if means can be found to combine economically the raw fibres, as in felts and papers. Fabrics combining glass with cotton, rayon and asbestos are now manufactured by combining the yarns of the desired types.

Potential processing uses include many evaporation, diffusion and fractionation applications in which the surfaces of the fibres may be wetted to increase greatly the film surface of a liquid that is to be evaporated or otherwise chemically or physically modified.

Filtering of air or gases, liquids and sludges by the straining method is cited as another potential field of use. The substantially cylindrical, smooth-surfaced fibres, Fig. 1, provide comparatively low resistance to the flow of liquids, yet the interstices between fibres may be modified to provide almost any degree of porosity by the choice of the proper fibre size and by the density at which the fibres are packed.

Still other potential processing uses are contact applications in which water is sprayed on the fibres to humidify or dehumidify air that is forced through them, and eliminator applications where the fibres are employed to gather free particles of water or other liquids entrained in the air stream.

PROPERTIES OF FIBRES.

The seven basic glass fibres now available are distinguished by differences in fibre diameter, tensile

*See "Physical Properties of Fiberglas Laminated Plastics," by Cecil W. Armstrong, Lockheed Aircraft Corp., The Iron Age, July 22, 1943, p. 51.

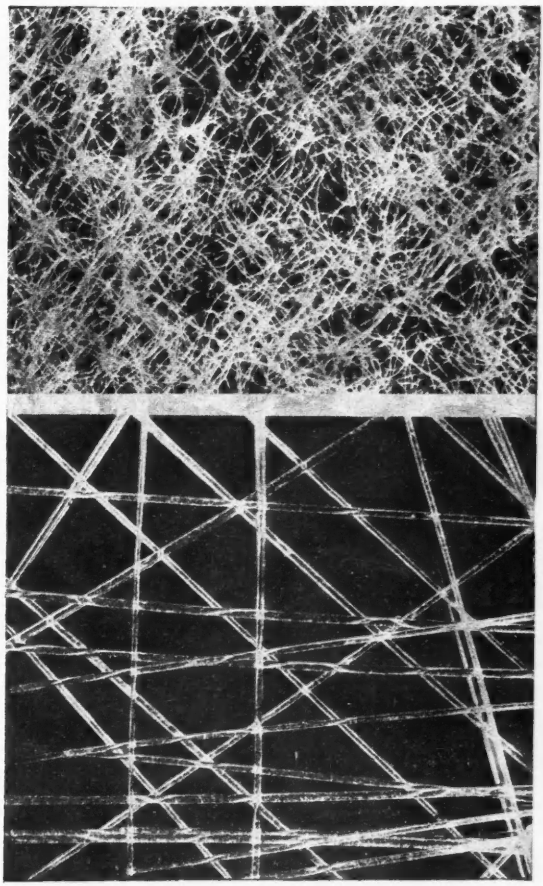
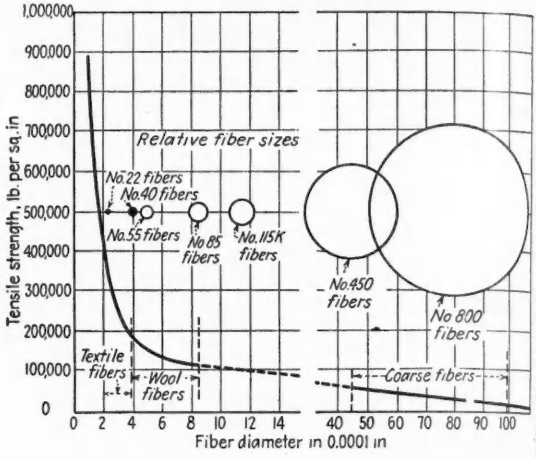


Fig. 1. Photo-micrographs of No. 800 and No. 115K glass fibres. The No. 800 fibre (bottom) is suitable for filtering, evaporating and contact mat applications where low resistance is required. The No. 115K fibre (top) is characterised by its curly nature. It provides very low density and high resiliency and offers maximum resistance to acid conditions.

Fig. 2 (left). Pad of No. 115K fibre shown enlarged in Fig. 1.

Fig. 3 (right). Tensile strength of Fibreglass basic fibres in relation to fibre diameter, adopted from studies made by Dr. F. O. Anderegg.



strength and the glass compositions employed, as shown in the accompanying table. Four glass compositions are used to provide different properties required for different applications. These properties, each of which is found in a substantial degree in all the fibres, and to a maximum degree in some, include resistance to acids, Fig. 2, and weak alkalis, to high temperatures and to severe exposure to weathering.

The four different glasses used are rarely interchangeable from one form to the other except as noted in the table of fibre properties. These different glasses are used to develop certain properties, as follows:

Type E glass was especially developed for the production of electrical insulating materials.

Type C glass is called a chemical glass because it is designed for maximum resistance to acid conditions.

Type T glass is used in thermal insulating products and combines good weatherability (endurance under alternating wet and dry conditions and temperature changes) with adaptability to production in wool forms.

Type F glass is made for air filter and related applications and is designed for economical production of coarse filter fibres only.

In many instances, the glass composition is not significant. Where the fibres are exposed to unusual service conditions, some experimentation may be necessary to determine which glass and which size of fibre will produce the most satisfactory results. It must be noted that fibre size and the corresponding surface area exposed to attack is an important factor in determining chemical durability under different service conditions.

Certain general characteristics should be used only as an approximate guide to comparative behaviour. Type E glass, for example, offers the maximum resistance to weather and may be used for severe exposure to water and steam. In exposure to weak alkalis it is slightly superior to Type C glass, which offers maximum resistance to acids. Where a combination of maximum weatherability and resistance to acid is desired, Type T glass is recommended, since its weatherability is only slightly less than E glass and its resistance to acids is greater. Type F glass is for coarse fibres only and cannot be properly compared with these other types of glass.

In temperature resistance, Type E glass shows slightly superior characteristics for exposures of short duration; for protracted exposures, all of the glasses

CHARACTERISTICS OF FIBREGLAS BASIC FIBRES.

Fibre Number	Glass Type	Fibre Diameter		Fibre Length Aver. (in.)	Fibre Lubricant or Coating	Surface Area per lb. of glass (sq. ft.)	Average Pack Density lb./cu. ft.
		Average (in.)	Range from Average				
800	F	0.00800	±0.0005	20	None	38.7	3.5
600	F	0.00600	±0.0005	20	None	47.5	3.5
450	F	0.00450	±0.0005	20	None	68.8	3.5
115K	C	0.00115	±0.00015	6	Min. Oil	262.0	0.5
85	E	0.00085	±0.00015	15	None	355.0	2.0
55	T	0.00055	±0.00030	6	Min. Oil	537.0	1.5
40	E(C) *	0.00040	±0.00010	15	None	755.0	2.2
22	E	0.00022	±0.00005	16	Starch	1370.0	1.5†

*No. 40 Fibre is normally made of E Glass. It can be produced from C Glass (C40) if volume and use warrants.

†Density after de-starching or spreading and fluffing. Density before spreading bundles of fibres may range up to 70 lb. per cu. ft. or more.

are substantially alike. The service limit is approximately 1000 deg. F.

STRENGTH OF FIBRES.

The chart, Fig. 3, shows the relationship between the tensile strength of glass fibres and their diameter. The values are based on several thousand tests but must be looked upon as theoretical rather than as realized values.

Various fibres are designated by a numbering system based upon the average diameter of the fibres multiplied by 100,000. Therefore, a No. 22 fibre has an average diameter of 0.00022 in. and No. 800 fibre has an average diameter of approximately 0.0080 in. The letter preceding the number is employed to designate the particular glass composition from which the fibres are drawn. When the number is followed by a letter, the letter distinguishes between fibres of like diameter that are made by different manufacturing processes.

ELECTRONIC SORTING AND TESTING

(From *The Iron Age*, Vol. 152, No. 19, November, 1943, pp. 57-58).

A RECENTLY developed electronic device, the Cyclograph, provides a unique method of sorting and performing non-destructive qualitative and quantitative metallurgical tests on ferrous and non-ferrous materials. The machine, designed by Allen B. Du Mont Laboratories, Inc., Passaic, N.J., has been adapted to checking evaluating and sorting of materials by such factors as machinability, toughness, internal stresses, structure, analysis, case depth, plating thickness and heat treatment.

The Cyclograph utilizes the principle that the metallurgical properties noted above cause variations on the core loss of a tuned pick-up coil which surrounds the piece under test. These variations affect the shape of an easily interpreted visible pattern or oscillogram displayed on a cathode-ray tube indicator screen (Fig. 1). By means of these pattern variations, a semi-skilled operator can determine differences in metallurgical properties of a number of ostensibly similar parts.

Where large quantities of samples are involved, such as in actual production test routine, the machine can be adapted to automatic sorting at speeds as high as 5 pieces per sec.

By inspection of the core loss characteristics of a metal at three, for example, properly chosen frequencies, the Cyclograph is capable of breaking down a given lot into smaller lots. Each of the pieces in each of these smaller lots will now have reasonable constant metallurgical properties except for the single property under test. After this preliminary selection test, the Cyclograph will then evaluate for each of these lots the single metallurgical property under test.

The procedure followed in sorting SAE and NE steels has been to select two or more frequencies which give a correlation between the instrument readings and the characteristic of the metal which is to be identified.

To do this, a graph must be plotted which shows the relative instrument readings as a function of the frequency and proper test frequencies chosen from this graph. Representative curves are shown in Figs. 2 and 3.

It can be seen that if an attempt were made to separate two different steels at any one given frequency, sooner or later some pair of steels which would give the same reading would be encountered. This is true of all types of magnetic testing using only one reading. It can also be seen that measurements at three frequencies of 3, 10 and 50 kilocycles are sufficient to establish definitely which curve any particular steel lies upon.

If it is desired to sort any two given steels according to analysis in a certain stage of heat treatment, a "measuring frequency" will be chosen at that point showing the widest difference in reading for the particular steels to be sorted. The standardizing frequencies will be the other two frequencies used.

To perform a practical separation of two steels, a sample of each of the two steels is obtained. A composite indication at two frequencies other than the measuring frequency furnishes a reading typical of each grade of steel. This is the standardizing reading. As each piece of steel is put in the instrument, its standardizing reading is taken. If the standardizing reading is one of the two values expected, the measuring indication shows which one of the two steels is the particular piece. If the standardizing reading is not one of the two expected readings, the steel is neither of the two steels the instrument is supposed to be sorting or else it is not in the expected state of heat treatment.

An automatic relay can be used in conjunction with the instruments in production sorting of small parts. This is only necessary where the quantity to be tested is large. The rate of sorting for small pieces, such as bullets or screws, is about 5 per sec.

ARMOUR PIERCING SHOT TEST.

In a suitable armour piercing shot, although hardness and stresses are not uniform throughout, a balance of internal stresses is reached. If a medium test frequency is chosen, a tough shot, in which the hardness gradient and distribution of internal stresses are as desired, gives a definite reading. If the hardness is higher or lower than desired, the reading will change because the relative values of core losses change. Similarly, increased internal stresses in any one area, as caused by having a surface layer under extreme

Fig. 1. Checking the case hardening depth of roller bearings on the cyclograph. The coil is contained in the square box, in which the pieces are placed. The pattern appears on one or the other of the cathode-ray tube screens used. Checking and sorting can also be done automatically, on the production line, the satisfactory pieces falling into one box, the rejects into another.

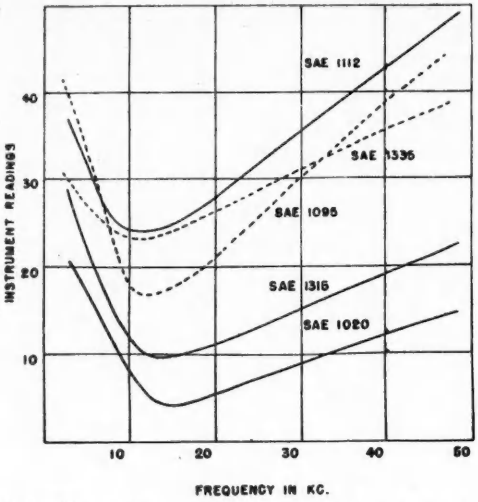


Fig. 2. SAE steels as rolled, showing the relative instrument readings as a function of the frequency.

stress, will greatly increase the high frequency losses which are only affected by changes in the surface layers of the shot. If the high frequency used is such that the field of flux penetration approximately coincides with the hardened zone of the shot, a very sensitive measure of stress distribution can be obtained.

In evaluating toughness of shot after heat treating, the instrument used on the hardened shot takes two standardizing readings at proper frequencies which establish that the shot is of the expected analysis and that heat treatment has not been erratic. A third or measuring frequency is used to determine the toughness or brittleness of the particular shot. These measurements can be done simultaneously or one after the other.

Low frequency measurements are successful in identifying pearlitic and spheroidized structures in bar stock. The most practical way of segregating bar stock as received, is first to separate pearlitic bars from spheroidized bars and then to grade spheroidized bars according to the per cent spheroidization, if desired.

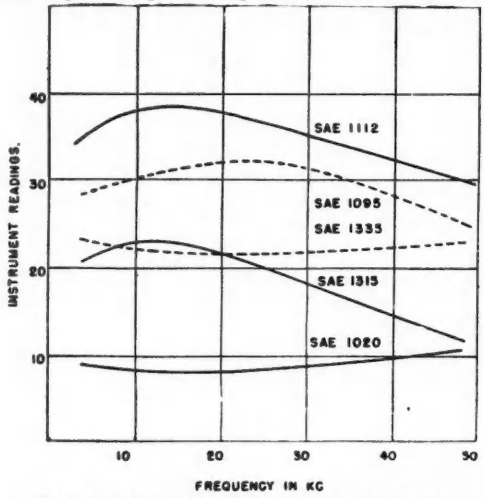


Fig. 3. SAE steels quenched and drawn, showing the relative instrument readings as a function of the frequency.

CASE DEPTH MEASUREMENT.

Several methods of quickly determining case depth by measurement of one or more magnetic or electrical properties are under development at present. All of these are comparative methods. A standard piece with known case depth is first used to set the instrument. Case depth may then be determined by substituting them in the instrument.

By careful design of test coils and proper choice of frequencies, a reliable indication of case depth can be obtained if the following procedure is carried out.

The case hardened parts must be inspected to ensure that all parts being compared have approximately the same magnetic characteristics in their cores; groups having the same core characteristics can then be inspected for case depth if their temperatures are reasonably constant.

In practice, one instrument is used to inspect the core characteristics. Differences in analysis, heat treatment and internal stresses are indicated. The parts are divided into groups which show the same magnetic properties by this method of testing.

Each group is then tested separately on a second instrument. Once the instrument is set up to measure case depth on any given group of parts which have been segregated according to core properties, no further adjustments are necessary. The parts are placed in the test coil and the case depth read from the cathode-ray tube screen. Rate of testing depends upon the speed of the operator, who needs no more technical training than a Rockwell operator. A production rate of testing on one single type of part should be between 20 and 30 pieces a minute.

MEASURING MECHANICAL VIBRATIONS.

(From *Westinghouse Engineer*, Vol. 3, No. 4, November, 1943, p. 135).

MR. H. C. WERNER and his associates of the Westinghouse Research Laboratories, have developed a simple, accurate and versatile device for measuring mechanical vibrations. The device, called vibrograph, is extensively used in industry to investigate vibration of high-speed rotating equipment, such as turbines, small motors and motor-generator sets. It can also be used for certain phases of plane-vibration tests and similar work related to the war effort.

The vibrograph is applicable to the analysis of vibrations encountered in machinery. It gives high precision results between 60 and 15,000 cycles per minute, but is also useful for vibration analysis considerably outside of this range. It records an amplitude range of from less than one ten-thousandth inch to as high as one-sixteenth inch.

Fundamentally, a vibrograph consists of a frame containing a mass suspended by a weak spring. A pointer attached to the mass indicates relative motion between the frame and mass when the frame is applied to a vibrating body. Ordinarily, the frame is placed upon the vibrating body and indicates displacement in one plane only. In cases where there is lack of physical space upon which to rest the vibrograph or when the mass of the frame of the instrument affects the vibrations, the instrument is hand-held and vibrations are transmitted by means of a prod. Replacing the pointer with a stylus or pin acting on a moving tape records the vibrations graphically.

In the Westinghouse vibrograph, both seismic and prod applications are combined. The manner of mounting and centering the mass of the instrument permits operation in any position. The stylus describes a track of the vibration on a moving celluloid ribbon and is viewed with a low-power microscope. Incorporated in the vibrograph is a newly devised timing device that leaves a trace on the ribbon allowing calibration of the vibrations under observation.

"MAGO" COUPLING made by METALASTIK LTD., Leicester, England.

By MAJOR A. GARRARD. (From *The Engineers' Digest* (American Edition), Vol. 1, No. 2, January, 1944.)

THERE is increasing recognition of the desirability or even necessity for the provision of elastic driving elements in the transmission from prime movers having cyclical torque variations or other cyclical variation due, for example, to want of balance. All internal combustion engines exhibit these characteristics to a greater or less extent, depending upon the number and arrangement of cylinders. Among other applications, mention may be made of clutch centers for motor vehicles, marine engine transmission, and aircraft auxiliary drives.

It is, however, essential that elastic elements in the transmission should include a damping characteristic, and it is in this connection that the rubber properties of high yield, high resilience, and viscosity or internal friction, are found to be of special value.

The "Mago" Coupling, made by Messrs. Metalastik Ltd., of Leicester, England, has been designed so as to utilize to the fullest possible extent the special properties of rubber. This coupling can be made with the resilient characteristics necessary for dealing with the variations in torque of high power transmissions, or can be designed so as to be suitable for use in low power transmissions. The rubber elements are subjected both to shear and to compression, but an increasing proportion of the resistance is taken up by compression as the torque increases. Full advantage is thus taken of the flexibility of rubber in shear at lower torques, and of the greater compressive resistance at higher torques. Figs. 1 and 2 show an asymmetrical construction applied to a motor vehicle clutch center adapted for transmission mainly in one direction, but having also provision for cushioning overrun torques. Fig. 3 shows a pictorial view of this clutch center. Adequate safeguards against shock loads in either direction are inherent in the design.

The driving and driven elements are formed with co-operating curved surfaces struck from centers on a base circle concentric with the axis of the shafts, thus forming a cam like groove or slot, the outer and inner series of elements being connected respectively with the driving and driven elements.

Rubber fills the space between, and is bonded to these inner and outer surfaces, the shape being such that the relative rotation of the two elements subjects the rubber to shear, while the surfaces, in addition, approach one another and compress the rubber between them. A shallow recess or groove runs lengthwise along the outer faces of the rubber, thus avoiding a convex bulge during compression beyond the metallic faces, and serving to relieve surface tension which occurs on contraction of the rubber during cooling after moulding.

During overrunning, torque is transmitted by compressing rubber between the steep shoulders connecting the long arcuate spaces, an opening being provided in the rubber at this point to avoid local stresses where the metal surfaces curve sharply.

If full advantage is to be taken of the special rubber characteristics, attention has to be given to the shape of the operating grooves. Otherwise it would be found that the rubber is stressed to varying extents, with the result that there may be excessive deformation at one point or region, and insufficient stressing at other regions. The resilience per unit weight of rubber would then be too low for its economical use.

With the object of obtaining uniformity of stress at all points along the length of the rubber inserts, the following geometrical construction is adopted.

Both inner and outer curves are of the same radius, and their centers are located as shown on the base circle, Fig. 1. The width of the rubber in the intervening space thus varies. If the rubber were removed, the inner and outer co-operating surfaces would finally make metallic contact so as to form a continuous curve. When arcs of circles are used, the common curve would be of constant radius but other geometrical curves could be used provided that they satisfy the conditions that they would, if making metallic contact, form a common continuous curve.

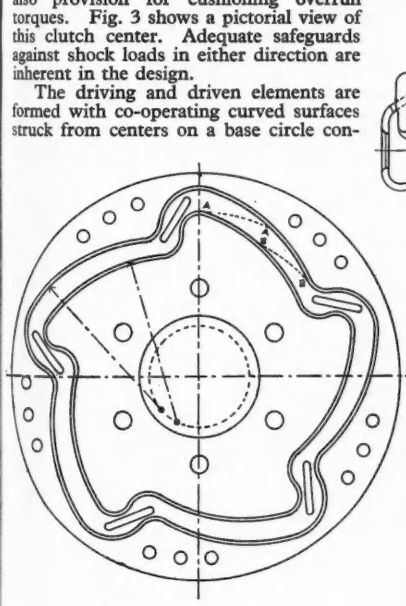


Fig. 1. **Clutch center.**

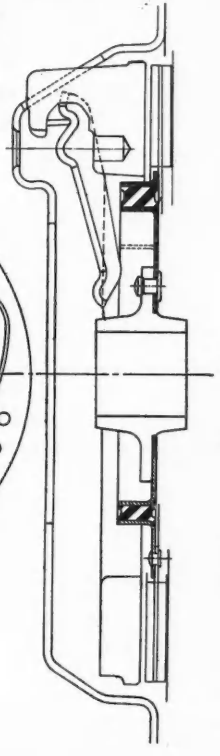


Fig. 2. **Clutch center.**

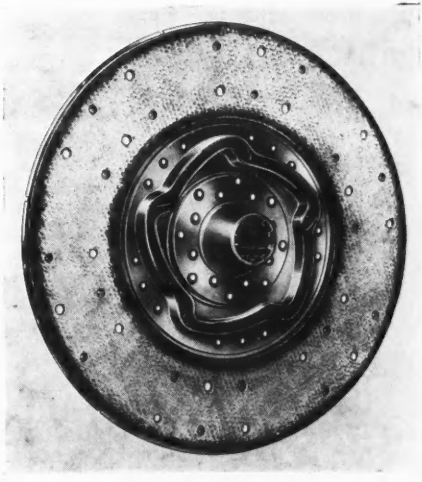


Fig. 3. **Clutch center.**

This is an essential characteristic of the design.

Arcs of circles A-A, B-B, struck from the axis of the shaft, define the path of movement of certain co-operating elements on the rubber during relative movement whereby shear and compression are associated in a predetermined relationship depending upon the design.

The transmission characteristics required, apart from the general scaling up or down, are thus dependent on the curvature of the bonded faces, the dimensions of the rubber insert, the diameter of the base circle on which the centers of the arcs are located, and the quality of rubber.

Torque and angular deflection curves for one design are shown in Fig. 4. The three pairs of curves correspond to three different grades of rubber, having different hardnesses of 70, 60, and 40 Shore durometer. Each pair consists of the static loading curve for the drive, and the static loading curve for the overrun. The torque deflection characteristic may be varied widely by changes only of the rubber quality.

The rising characteristic is desirable in this class of coupling. The results plotted cover only working limits. Beyond such limits, under emergency shocks or overloads, the curves would tend to become steeper indicating a rapidly increasing proportion of compression resistance.

The damping force characteristic of rubber is particularly important in this coupling. Its value at any instant is proportional to the velocity of distortion of the rubber at that instant, and as it resists movement in either direction, it provides a very simple and effective means for absorbing energy and reducing or limiting resonance.

Continuous running at resonant speed creates the most exacting conditions. When the torsional variation or forcing torque has a frequency which equals the natural resonant frequency, the amplitude of vibration is such that the energy derived from the forcing torque equals the energy absorbed in overcoming the viscosity of the rubber. There is thus continuous generation of heat, and as rubber is a poor conductor of heat, special attention has to be given to the design of the metal elements to which the rubber is bonded, to ensure that the temperature attained by the rubber is within suitable limits.

Cyclical variations of torque which occur with all multi-cylinder engines bring about continuous deflection and restoration of the rubber with corresponding

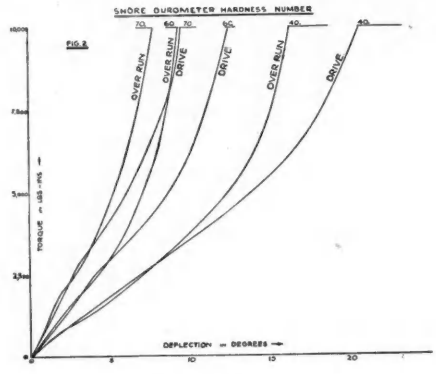


Fig. 4. Torque and angular deflection curves.

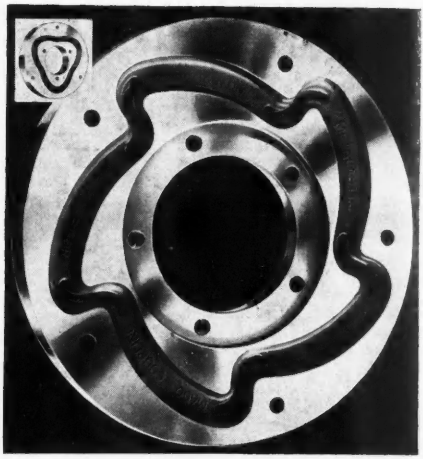


Fig. 5. Heavy type asymmetrical coupling for marine transmissions, and light symmetrical pattern (insert) for sensitive auxiliaries.

viscosity resistances appearing as heat. The design of the coupling as a whole, must be such as to ensure that heat is dissipated at a sufficiently high rate.

The asymmetrical coupling illustrated, is made with cushioning elements intended to provide an effective drive in one direction, and further cushioning elements having different characteristics for dealing with overrun torques, both drives giving adequate protection against shocks or overloads in either direction. When used as clutch centers in motor vehicles, the asymmetrical design has special advantages, since the period of noise in the drive often lies in a different range from that in the overrun. The clutch can be designed so that these two characteristics can be suitably related, the rubber being in shear and compression during forward driving, while during the overrun it is first in shear and tension, and then in compression. A heavy type of asymmetrical coupling intended particularly for marine transmissions, is illustrated in Fig. 5, while the insert on this figure shows a very small symmetrical pattern intended for cushioning the drive to sensitive auxiliaries.

The "Mago" coupling forms a safety device providing an unusual combination of flexibility in the early normal stages of deflection, of rapidly increasing resistance during overloads and shocks, and of simple energy absorption or damping. Smaller diameter couplings can thereby be used as compared with other plain shear rubber couplings, while the protected position of the rubber and the interaction between the specially shaped surfaces gives a high degree of protection against shocks and overloads.

By this means, it has further been found possible to design couplings with the certainty that they will adequately cushion and damp torsional vibrations of engines to such an extent that breakage of engines, propellers, or other associated parts driven thereby, will be reduced or avoided.

Information on Synthetic Rubber.—Information Circular No. 7242, prepared by, and obtainable from the Bureau of Mines, Department of the Interior, Washington, D.C., contains a list of the various types of synthetic rubber, their manufacturer, the manufacturing methods and other descriptive information on this important war material. The paper discusses not only the synthetic materials manufactured in the United States, but also those made in Great Britain, Russia, Germany, Japan and Belgium. It includes also a description of the principal raw materials employed in the production of synthetic rubber.

DEVELOPMENT OF SUPER-TENSION CABLES IN GREAT BRITAIN.

By F. W. MAIN, M.I.E.E. (From *The Engineers' Digest* (American Edition), Vol. 1, No. 2, January, 1944.)

THE increased mechanisation in industry and, indeed, in most of the affairs of Man has augmented the general electrification of factories, collieries, railways and even the home, resulting in acceleration of the general demand for electric power.

In Great Britain industrial and residential areas are more concentrated than in some other countries, and the result is a greater proportion of buried cable to overhead transmission lines.

The cost of transmission and distribution of electricity, especially by underground impregnated-paper cables, is such a large proportion of the total cost of electric generation and supply that it is necessary to transmit the power in bulk to distributing centres at the highest possible voltage in order to reduce the quantity of copper per cable and the number of cables sharing the load. With the progressive increase of transmission voltage, attention has been more and more directed from the conductor to the dielectric of the cable.

Cables to-day are regularly being made for a working voltage of 132-kV. ; there is one installation in Europe working at 220-kV. ; and cables are now being designed for 264-kV. For the same type and quality of materials, for the same fundamentals of design, and for the same construction, the thickness of dielectric must be increased as the voltage is raised if calculations be based upon an accepted voltage stress.

It can be shown that

$$S = \frac{kV}{x \log_e \frac{R}{r}} \quad \text{then} \quad S_c = \frac{kV}{r \log_e \frac{R}{r}}$$

and

$$S_s = \frac{kV}{R \log_e \frac{R}{r}}$$

therefore

$$\frac{S_c}{S_s} = \frac{R}{r} \quad \text{or} \quad \frac{S_c}{S_s} = \frac{r + t}{r}$$

where S = Electric stress as kV./cm.
x = Radius of any point in the dielectric in cms.
R = Outer radius of dielectric in cms.
r = Radius of conductor in cms.
S_c = Stress at surface of conductor, which is the maximum stress.
S_s = Stress at outer surface of dielectric which is the minimum stress.
t = Thickness of dielectric in cms.

For a given conductor size it will be seen, therefore, that as the voltage is increased and the dielectric thickness is correspondingly increased, the ratio of the stresses also increases and, as Sc is the limiting factor, the dielectric as a whole is less efficiently employed than at the lower voltages.

Practically all power cables so far have been manufactured employing impregnated paper, applied in tape form, as the dielectric, which cables are usually designated " straight type " or " mass impregnated " cables, and a more satisfactory alternative dielectric has up to now not been produced.

To limit the diameters of super-tension cables on account of weight which affects handling especially during installation, and in order to satisfy economic considerations, the thickness of the dielectric must be kept to the absolute minimum by increasing the voltage stress through the dielectric.

For this purpose the following are some of the considerations controlling the maximum possible or practical voltage stress that can be employed : general design of conductor such as number of wires in the strand, diameter and nature of surface ; dielectric dimensions ; shape and conditions of surfaces bordering the electric field of the dielectric ; and the quality of materials which is always of constant concern. The 3-core belted cable design has a limited voltage range due to failure by tangential electric stresses in the dielectric between the cores.

The first important step towards making a 3-phase cable suitable for higher voltages was to eliminate these tangential stresses by electrically screening each core before laying-up the 3 cores together. This, however, only filled the gap for a time between cables for 11-kV. and cables for 33 or 66-kV.

Ionisation in a cable eventually leads to breakdown, and one cause is the formation of voids in service. There is an unequal expansion of the oil and of the paper during the heating of the cable, and a relative movement between these two constituents takes place ; this is followed by cooling of the cable when the oil is unable to resume its former position in the dielectric, consequently low pressure voids are formed specially over the surface of the conductor—the area of maximum electric stress. These voids ionise due to this electric stress and the process is cumulative forming " tracking " until cable failure occurs. Fig. 1 shows a sample of paper tape removed from a cable after failure, showing the tracking mechanism. This phenomenon, due to fluctuating loads, again limited this type of cable to 33 or 66-kV.

Fig. 1

Reference has been made to well manufactured cable as being essential for the success of new developments in design. This has always been accepted by The

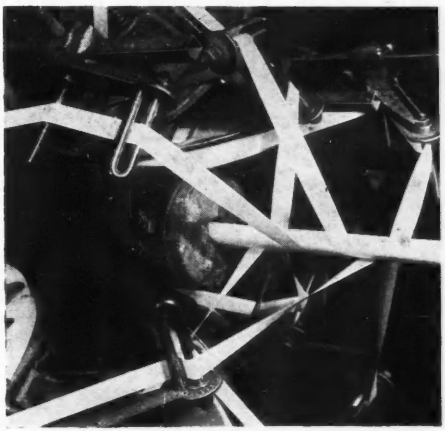


Fig. 2

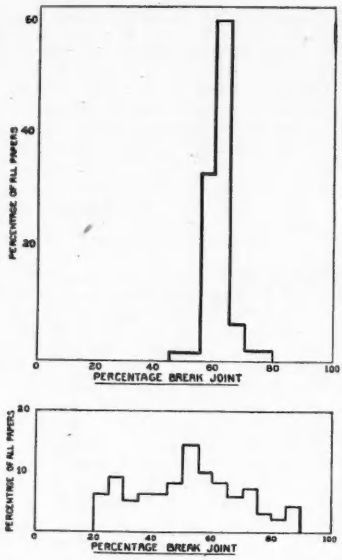


Fig. 3

Enfield Cable Works Ltd., who also realised that the results of development and research are lost unless in the factory there are employed efficient methods and good workmanship with effective supervision.

Studies have been made of every process so as to utilise the dielectric material to the maximum advantage, and the following are brief details of some of these.

Stranding : — Individual wires are examined to eliminate any having defects. For multi-core cables the conductors are prespiralled ; careful visual inspection and measurements of the strand are made during the operation to check the shape.

Dielectric: —Measurement of the registration and tension of the individual paper tapes are made to ensure that the tapes " break joint " correctly layer by layer and are also not coincident, otherwise coring and tracking in service would be assisted. Correct taping also reduces the volume of compound in the dielectric to a minimum which again lessens the possibility of ionisation. Fig. 2 shows a paper lapping head and Fig. 3 indicates the difference between good and bad lapping.

Drying and impregnation :—In order to obtain low dielectric power factors thorough drying and impregnation are imperative. Impregnating tanks have been designed in which vacuum values less than the equivalent of a pressure of 0.1 m.m. of mercury are obtained. Air is carefully excluded from the compound to prevent oxidation. Each operation is controlled and the condition of the compound is checked by electrical tests.

Lead covering :—The extrusion presses are designed to prevent oxidation of the lead in order that sheaths free from weak seams are produced. The cables are fed into the press from the original trays used in the previous process and the cables are continually submerged in cold compound until they are passed into the die-box of the lead press. Oil pressure containers are fixed to the cable ends immediately after lead covering and compound is thereby forced into the cable during cooling.

In spite of these precautions, the break-down-stress values for the dielectric of a virgin cable were found less than those for a single thickness of impregnated paper, and this disparity was ultimately solved by two new cable designs—the oil-filled cable and the compression cable.

The effect of mechanical pressure on the electrical break-down-stress of a dielectric was first demonstrated by Fisher and Atkinson in 1922. Later Hochstädter patented a cable applying the mechanical pressure to the dielectric through the medium of a flexible membrane, and from this has evolved the compression cable system sponsored and developed in England by The Enfield Cable Works Ltd. The construction consists of a normal solid-type cable with a lead sheath of non-circular section (SO. or oval) acting as the membrane or diaphragm surrounded by an outer member that contains the pressure medium which invariably has been nitrogen gas at 200 lbs. per sq. inch.

This outer member is either a protected steel pipe (pipe line type), or a further lead sheath reinforced to withstand the pressure (self-contained type) ; see Figs. 4(i) and 4(ii).

High voltage break-down tests on the compression cable have given values of 400-kV. per cm. approaching that for a single impregnated paper. Fig. 5 illustrates the effect of gas pressure on the power factor of a cable during heat cycles.

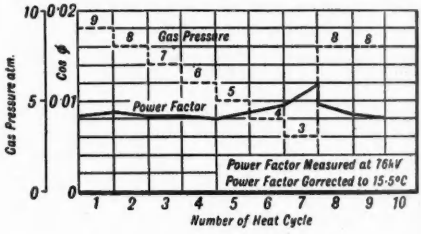


Fig. 5

It should be realised that when mechanical pressure is applied to the dielectric, not only are the larger ionisable spaces (due to load conditions) prevented from forming, but the inherent microscopic spaces are suppressed and the thickness of insulation can be reduced to less than half that required for solid-type cables.

It is realised that rigid research tests are necessary before a new design of super-tension cable can be put into commercial use, the most important being the " long-time " stability test taken on a length of cable fitted with sealing bells and joints, installed in the ground. The cable is submitted to heat cycles, i.e., the conductor is loaded until the temperature is raised to a value in excess of that in service and the cable is then allowed to cool; these cycles may be daily or weekly cycles. A voltage greater than the working voltage is

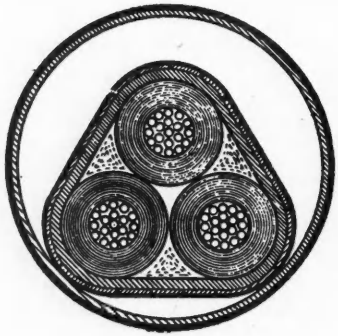


Fig. 4 (i)

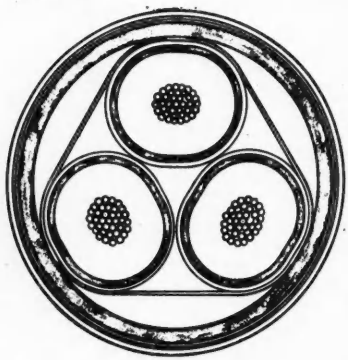


Fig. 4 (ii)

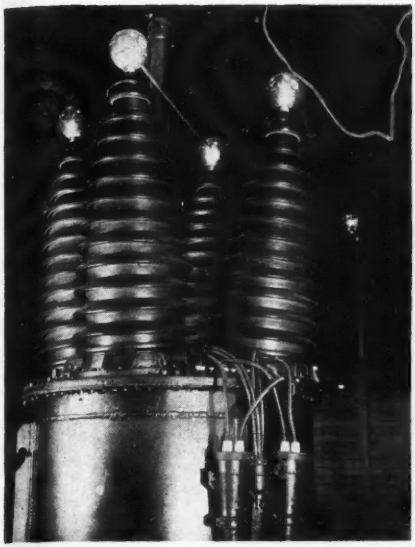


Fig. 6

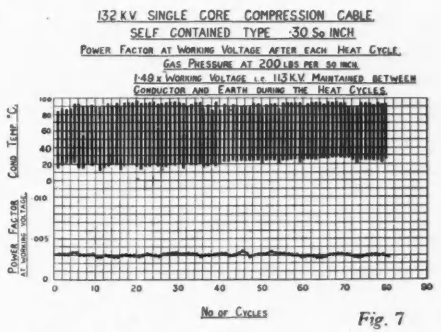

132 KV SINGLE CORE COMPRESSION CABLE
SELF CONTAINED TYPE ·30 Sq INCH
POWER FACTOR AT WORKING VOLTAGE AFTER EACH HEAT CYCLE.
GAS PRESSURE AT 200 LBS PER SQ INCH.
1·49 x WORKING VOLTAGE i.e. 113 KV. MAINTAINED BETWEEN
CONDUCTOR AND EARTH DURING THE HEAT CYCLES.
COND. TEMP °C.
POWER FACTOR
No. OF CYCLES

Fig. 7

maintained between the conductors and to earth. The criterion of the behavior of the cable is determined by the power-factor variation as measured by the Schering Bridge. The cable is subjected to a number of heat cycles often a hundred or more before complete satisfaction is agreed upon, and the period required for such a test is about twelve months.

These tests require high-voltage equipment, and Fig. 6 shows part of the high-voltage test plant in the laboratories of The Enfield Cable Works at Brimsdown, England, including high-voltage transformers each capable of 500-kVA. output at 500-kV. There are additional transformers for supplying the loading current for heating the conductor while under the test voltage. Fig. 7 shows the results of a long time stability test for a single core self-contained compression cable for 132-kV. the designed stress of which is 100-kV. per cm.

The first commercial compression cable in the world was a 2½ mile length laid between Hackney and Walthamstow, London, for the Central Electricity Board more than eleven years ago. The chief characteristics of the installation are :—

3-core 0.15 sq. inch "SO." pipe line type transmitting 31,500-kVA. at 66-kV.

Dielectric thickness 0.34 ins. (70 kV./cm. max. stress)

Overall dia. of cable 3.0″

Diameter of steel pipe 4.75″.

The installation has been completely successful, and it might be emphasised that during the whole of the period of service the gas pressure has never been released. The only accessories necessary were a compensator for the changes in volume of oil in the sealing bells due to temperature variations and for transmitting the pressure to the oil, also a unit for replenishing the gas in the event of leakage.

To summarise : the outstanding advantages of the compression cable system are, complete suppression of ionisation resulting in reduced cable dimensions and greater reliability at increased operating temperatures, suitability for voltages up to at least 264-kV., normal cable construction, and simplicity of accessories.

For super-tension cables it is extraordinary that the only dielectric material is paper impregnated with compound having an oil base which has held the field for sixty or more years.

The cable research engineer is still seeking for a dielectric material that will satisfy the following requirements :—

To be homogeneous, inert, flexible, free from any reaction with copper ; preferably non-hygroscopic, unaffected by ozone, voidless ; to have low coefficient of expansion, low thermal resistance, reasonable dielectric resistance, low permittivity, low power factor with a flat temperature power-factor curve, very high dielectric strength, stability under high electric stress, high resistance to electric surges ; and all characteristics must be unaffected by temperatures from —10° C. to +100° C. ; also it must be amenable to easy application to the conductor, and to the application of standard methods of protection. Finally, the cable should not require in service any auxiliary apparatus, nor should it call for any maintenance, which is the happy position with lower voltage cables.

THE K-PROFILE SHAFT SEAT

By C. WOLF. (From *Fertigungstechnik*, No. 4, July, 1943, pp. 82-83.)

THE K-profile shaft seat is finding increasing application in aero-engine and vehicle construction, as it eliminates difficulties experienced with the fabrication of serrated seats. In recent years its employment has also met with great success in machine-tool and general machine construction. However, in spite of its great simplicity and low cost of manufacture, an uncritical general employment of this novel type of seat will not be possible, and further research will be necessary to clarify such points as its distending effect upon the hub into which it is cut. Nor will laboratory tests alone be sufficient to adjudge this type of seat, since practical experiences may not be in consonance with theoretical considerations or laboratory tests.

Except for such cases, the employment of the K-profile seat has already become so widespread that it can justifiably be considered as an important new element in machine construction. The contour of this seat is a combination of geometrical curves, the whole resembling an equilateral triangle with rounded-off corners. Its production is carried out by means of a special grinding machine suitable for both external and internal grinding. Instead of producing the contour from templates or by shaped cams, the grinding wheel

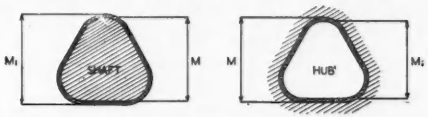


Fig. 1. K-Profile seat showing shaft and hub tolerances.

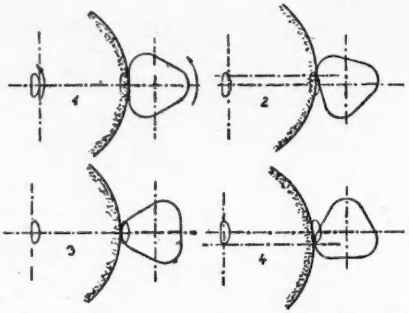


Fig. 2. Inter-relationship between movement of grinding wheel spindle and rotation of work piece.

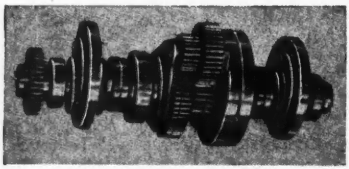


Fig. 3. Assembly of eccentrics (interchangeable).

Fig. 4. K-Profile grinder set for internal grinding.

spindle of the machine is made to describe the required contour by means of a set of eccentrics, of which three different assemblies can be inserted into the grinder according to requirements. By means of a planet gear drive, the work piece itself is accelerated and decelerated as flanks and corner points respectively pass under the grinding wheel. An inherent advantage of this grinder is that grinding accuracy is independent of the diameter of the grinding wheel. Hubs and shafts can therefore be ground on different machines without jeopardising a perfect fit. Change-over from internal to external grinding is easily accomplished by means of a lever changing the position of the swivel table. While it would be possible to grind the final contour out of the solid material, preliminary machining to approximate dimensions is recommended. For this purpose, a special contour machining device has been developed which can easily be fitted to any ordinary lathe, the device being equally suitable for external and internal machining. This device can also be applied to the machining of conical shafts and hubs, as well as to blind holes. Special machines of larger capacity are under development.

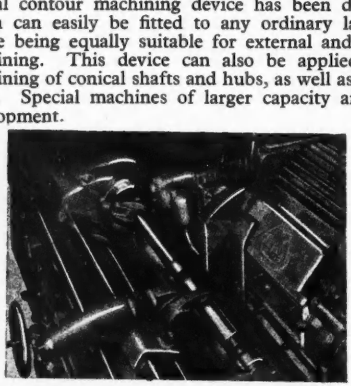


Fig. 5. K-Profile grinder set for external grinding.

For the pre-cutting of the bore, the broaching process is particularly suitable; and where hardening is not required, the piece can be broached to finish immediately. All profile dimensions are made to factory standards, which can be checked with the usual calipers, etc.; but special tolerance gauges for bores and high precision gauges for special purposes have also been developed.

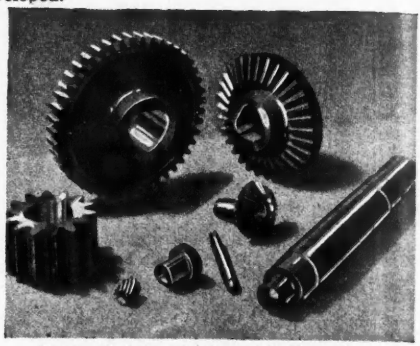


Fig. 6. Typical applications of the K-profile seat.

MILLING STONE WITH METAL CARBIDE CUTTERS

By H. EBERHARDT. (From *Zeitschrift d. VDI*, Vol. 86, 1942, No. 43/44, p. 653.)

TESTS have been carried out to use existing carbide-blade milling cutters for shaping stone blocks to be used in large buildings. The stones used were limestone, marble, travertine, porphyry and granite. The most favourable cutting speeds and feeds are recorded in Table I. Granite could not be machined, as even with a low cutting speed the quartz content caused very large tool abrasion. The machined surfaces of the other stones were smooth and ready for polishing. Wear of the cutting edges was small.

To save the milling cutters, the blocks were roughly pre-ground to shape with silicon carbide grinding wheels (Fig. 1). The remaining narrow slabs were broken off and the half-round groove was milled to size with a profile cutter, the plane faces with a facing cutter (Fig. 3).

The cutter had a 420 mm. diameter, 14 exchangable and adjustable blades. A 0° rake angle gave the best results, for varying stone hardness. With down-cut milling, the stone edges at the end of the cut did not crumble away. The cutter blades should be re-ground from five to eight times.

TABLE I. Cutting speed and feed for milling with carbide cutters.

Stone	Cutting speed	Feed
Limestone (similar to travertine)	m/min. Up to 25	m/min. Up to 1,000
Rochlitz porphyry	„ 60	„ 1,500
Strong, compact limestone ..	„ 40	„ 800
Lauster travertine	„ 60	„ 1,500

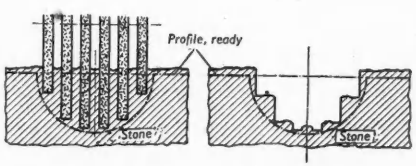


Fig. 1 Fig. 2 Fig. 3

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

THE APPLICATION OF "WIMET" TO RIVETING.

An interesting application of tungsten carbide has been introduced by Messrs. A. C. Wickman Limited, Coventry. This company, to fulfil the demand for the increased life of riveting punches, has evolved a very successful tungsten carbide tipped riveting punch, which has now concluded a series of stringent tests in a shell case manufacturing works. It has proved successful under extreme conditions of operation and it may be of interest to indicate how this new application of "Wimet" has efficiently and economically increased production, eliminated frequent replacement and reduced maintenance to a minimum.

This latest application has been designed for cold riveting the base plug of H.E. steel shell cases. Prior to the introduction of this punch, this operation was carried out with punches of high speed and other hardened alloy steel punches used in conjunction with a high speed percussion riveting hammer operating at 360 blows per minute. This was costly and required frequent punch replacement as only approximately 150 base plugs could be riveted with the high speed steel and approximately 350 with the other hardened alloy steel punches. The Wickman "Wimet" tipped riveting punch, made from a solid nickel chrome steel shank recessed for the brazing of the tip, has successfully riveted over 100,000 base plugs without maintenance of any kind and is still in perfect condition.

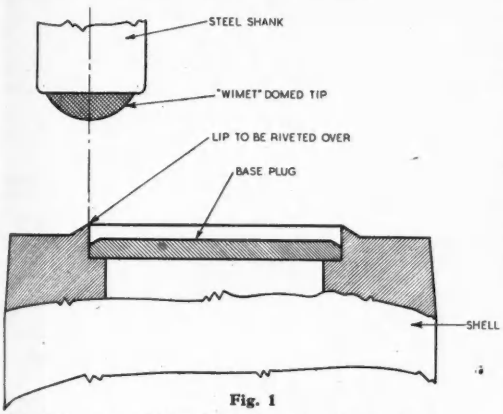


Fig. 1

Fig. 1 shows the "Wimet" tipped punch and the operation performed. It will be observed from the foregoing that this new application opens the field for further applications of a like nature, giving economical and efficient production, with long life and minimum maintenance.

Bibliography of Glass.—The National Bureau of Standards, Washington, D.C., has prepared a new Letter Circular, LC728, Bibliography on the measurement and gauging of gears. One hundred and eighty-five articles with brief abstracts are listed in approximately chronological order, followed by subject and author indexes. The references are numbered, using a system that indicates the year of publication. Copies are obtainable upon request from the N.B.S., Washington, D.C.

PERSONAL.

Mr. F. E. S. Beavan, D.S.O., M.I.N.A., general manager of the Mountstuart Dry Docks Co. Ltd., has been elected President of the Shipbuilding Employers' Federation.

Mr. G. E. Beharrell has been appointed joint managing director of the Dunlop Rubber Co. Ltd.

Mr. A. G. E. Briggs and **Mr. H. H. Burton** have been appointed Directors of The English Steel Corporation, Ltd.

Mr. I. S. Buchanan, C.B.E., has been appointed Assistant Chief Executive at the Ministry of Aircraft Production.

Mr. Fred. Cooper, designer of a number of famous high-speed boats—amongst them Sir Malcolm Campbell's Bluebird, which won the world's water speed record in 1938—has joined the staff of Rotol, Ltd.

Mr. F. T. Dyer, A.M.I.Mech.E., has been appointed works manager of the plough and implement factory of Messrs. Ransomes, Sims and Jefferies, Ltd.

Mr. I. Eccles, B.Sc., M.I.E.E., A.M.I.Mech.E., has been appointed city electrical engineer of Liverpool Corporation Electric Supply.

Mr. A. G. Higgins, M.Sc., has been appointed assistant secretary of the Institution of Gas Engineers.

Hopkinsons Ltd., celebrate their Centenary. Hopkinsons Ltd., the well-known manufacturers of boiler mountings and valves celebrate the completion of 100 years continous engineering activities.

Mr. Alexander McKechnie, Chairman of Messrs. McKechnie Bros., Ltd., Birmingham and Widnes, has died recently.

Mr. Leonard Moritz has been appointed Director of British Timken, Ltd.

Lt.-Col. Edgar Pam has been elected president of the Institution of Mining and Metallurgy for the Session 1944-45.

Dr. A. M. Robb has been appointed to the Chair of Naval Architecture in Glasgow University.

Mr. W. J. Terry, Chairman and Managing Director of the London Electric Wire Company and Smiths, Ltd., and Managing Director of the Liverpool Electric Cable Company, Ltd., has been elected Chairman of the Cable Makers Association for the second year in succession.

Mr. T. Watson has been appointed to the Board of Directors of General Refractories Ltd., Sheffield. Mr. Watson joined General Refractories in 1929, and since 1931 has held the position of Commercial Manager of the Company.

HEAT TREATMENT SPECIALISTS

ON APPROVED LIST OF AIR MINISTRY AND ADMIRALTY

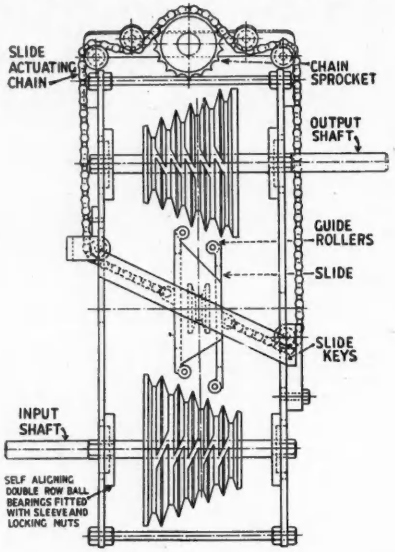
- Case Hardening and straightening up to 8 ft. long.
- Hardening all Classes of Sub. and High Speed Steel Tools, Bakelite Moulds and Press Tools.
- Hardening by the Shorter Process.
- Cyanide Hardening, Capacity 3 tons per week
- Springs: Any size, shape or quantity.
- Aluminium Alloys Heat Treated to A.I.D. Specifications.
- Heat Treatment of Alloy Steels up to 10 ft long
- Heat Treatment of Meehanite Castings, etc.
- Crack detecting on production lines.
- Chemical blacking to A.I.D. Specification.

THE EXPERT TOOL & CASE HARDENING CO. LTD.
(Est. 1918)
Phone LIBERTY 2273-4
MORDEN FACTORY ESTATE : LONDON : S.W.19
And GARTH ROAD, LOWER MORDEN, SURREY.
Telephone: Derwent 3122

NEW POWER TRANSMISSION REPLACES THE GEAR-BOX.

A NEW invention, the "N and B" Speed Change Power Unit, recently placed on the market by The Newey Engineering Co., Ltd., Brook Street, Nottingham, is on the step pulley principle, but so arranged that the speed can be changed without stopping the machine or touching the belt by hand.

The unit consists of a small and compact casing, in one standard form 21⅛ by 10⅛ by 8 in., replacing the gear box or ordinary step pulley, allowing of power transmission within the range of ¼-2 h.p., with six different speeds, which are changed over from one to the other, up or down, almost instantaneously, merely by operating a handle. Other sizes are available up to 7 h.p. transmitted, while the number of speed changes can be more or less than six, as required.



The basic principle consists in using two sets of step pulleys, each formed in one piece, having the required number of grooves or steps, operated by a short "V" belt, and the speed change is carried out by making both the driving and driven step pulley blocks with transverse interconnecting grooves. Consequently when the "V" belt is pushed sideways in either direction it slides smoothly through the lateral grooves from one set of step pulleys or straight driving grooves to the other, thus changing the speed immediately, without interrupting the running. The action is carried out by means of a light inner vertical framework, between the two step driving pulleys, which encloses the driving belt, and this framework is caused to move, along with the belt, in a lateral direction as desired by means of a small endless slide acting chain, carried on spur wheels, operated by revolving the change handle, which is at the top. Normally the driving or input pulley and shaft is at the bottom, running at say 2000 revs. per minute and the driven or output shaft at the top, which in the 6-step unit can be given a speed of say 2000, 1538, 1129, 886, 750, or 500 revs. per minute (or other proportion). The operating handle has a graduated quadrant with 6 interlocking holes, corresponding to the speeds, whilst all the moving parts are carried on ball bearings. A spring loaded jockey pulley and a guide pulley is included, and keeps a constant tension on the belt, although allowing slight extra length when changing speeds. The cost is much less than that of a corresponding gear-box, and replacements merely consist of an occasional belt costing two or three shillings. Whilst another advantage is that no oil is required, except for a few spots on the sealed bearings.

WAR EMERGENCY B.S. FOR SPOT WELDING FOR LIGHT ASSEMBLIES IN MILD STEEL (B.S. 1140).

THE above Specification relates to the application of spot welding to the fabrication of mild steel assemblies comprising two or more thicknesses of metal.

The various applications have been classified under two broad headings, determined by the relation between the mechanical strength of the structure and individual welds; the essential features of the types of welding machine for these two classifications are laid down.

The Specification defines the chemical composition for the parent metal and includes recommendations as to suitable steels.

Mechanical tests are not included as the Specification is chiefly concerned with procedure, for which there are appropriate clauses together with requirements for workmanship and inspection. Price 2s.

Some Bites

The Shark's

In whatever position the shark attacks — the upper jaw is a comparatively immobile gripping member, against which the lower jaw bites with upward leverage. Jaw muscles provide the necessary elasticity to ensure unshakable grip.

Note the diagrams—see how the construction of THE EVERTITE embodies the natural principle of :—

1. Biting upwards with its lower jaw.
2. Natural elasticity of its "mouth."

Like the shark—"Evertite" needs no extraneous gadgets (top nuts or spring washers) to ensure its grip. Like the shark—it takes a normal "bolt."

EVERTITE

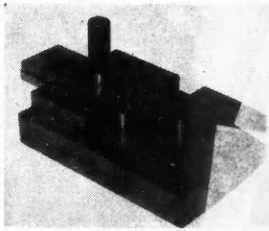
NUTS & BOLTS (Darlaston) Ltd., Foster St., DARLASTON

NORBURY

TOOLS AND GAUGES

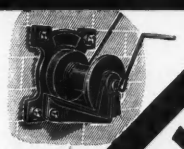
JIGS AND FIXTURES

JIG BORING



THE NORBURY ENGINEERING CO. LTD.
GREAT NORBURY STREET,
HYDE, CHESHIRE.
Phone & Grams: - - HYDE 93

YES A POWERFUL ROBUST SELF-SUSTAINING WINCH



Hundreds of thousands supplied during last 40 years to Govt. Depts., Corporations, Railways, innumerable traders, etc. Will not run back. No wheels to get caught in.

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USED LARGELY FOR BLACK-OUT SHUTTER OPERATION

DIRECT DRIVE & RATIOTYPES

Also used for Blinds, Aeroplane Hangars, Electric Light Fittings in Halls, Hotels, etc. Dampers, Curtains, Laundries, Steamer Lids. Hospitals. Signs. Street Lighting. A.R.P. Clothes Racks, Railway Station Lighting, Hoses, etc.

Phone: Uplands 4871/2 (2 lines)

NO RATCHETS, PAWLS, SPRINGS, OR GEAR WHEELS

THE LONDON ELECTRIC FIRM. CROYDON.

For Optimum Hardness and Strength

Nitrided NITRALLOY STEEL

Particulars from:

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Telephone: 60689 Sheffield

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SPECIAL ALLOY AND HIGH CARBON STEELS

BARS—WIRE RODS
PLATES — SHEETS

THE HALLAMSHIRE STEEL and FILE CO., LTD., SHEFFIELD 3.

Established 1873

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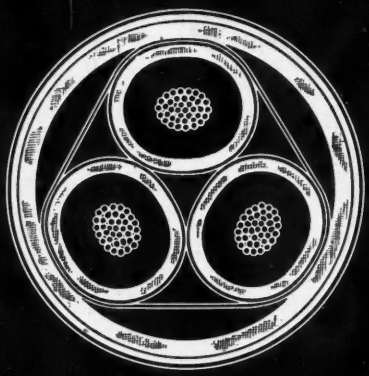
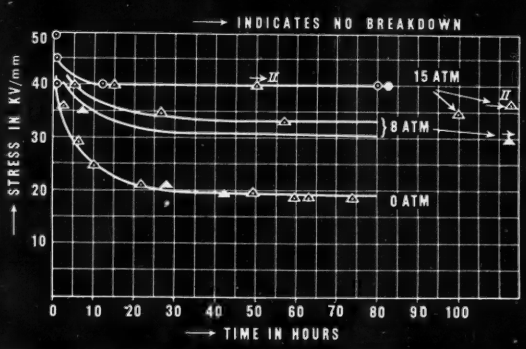
ENFIELD CABLES

SPECIALISTS IN · · · · ·



66kV Compression Cable SELF-CONTAINED TYPE



TIME-VOLTAGE CURVES OF CABLES UNDER DIFFERENT EXTERNAL PRESSURES.

THE ENFIELD CABLE WORKS LTD., BRIMSDOWN, MIDDLESEX Telephone: Howard 2661 (10 lines) C4

An enlarged part-sectional view of a Metalastik bush.

METALASTIK BUSHES

A triple advantage
that can't be seen!

A Metalastik bush is very different from an ordinary rubber-in-compression bush.

Instead of relying on compression-plus-friction, the rubber in the Metalastik bush is firmly 'welded' to the inner and outer metal sleeves, and functions in three ideal ways:—

(1) Deflection and frequency are controllable in shear, both axial and torsional.

(2) The rubber-to-metal-weld resists separation of the rubber from the metal under tension stress.

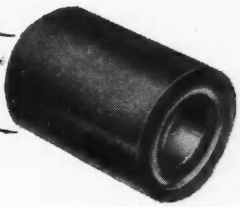
(3) In compression, as well as in shear and tension.

We design these bushes to meet required frequencies or damping, using natural or synthetic rubber, welded to all metals in ordinary use.

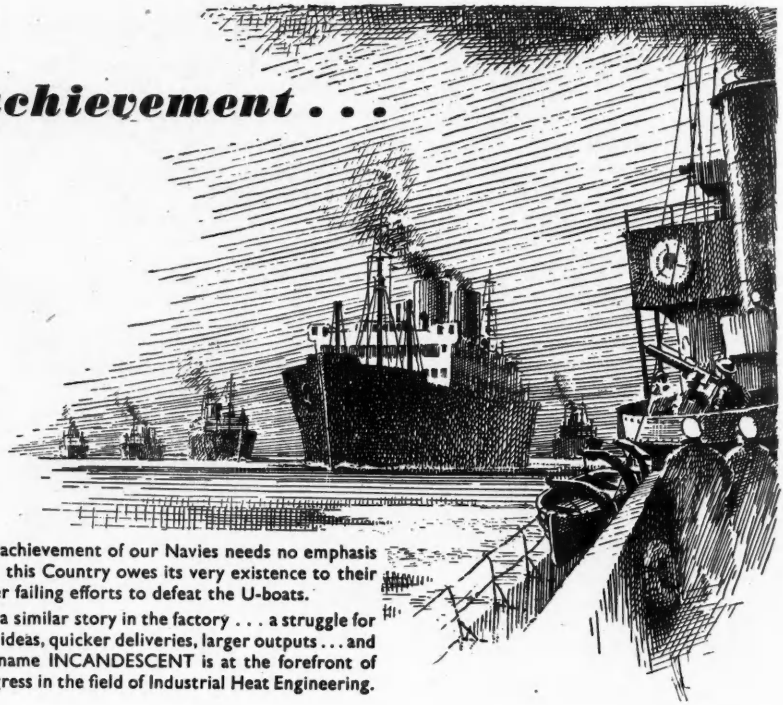
Our technique and experience enable us to provide bushes for many fresh applications where rubber could never be entertained before.

Metalastik Ltd., Leicester.

METALASTIK

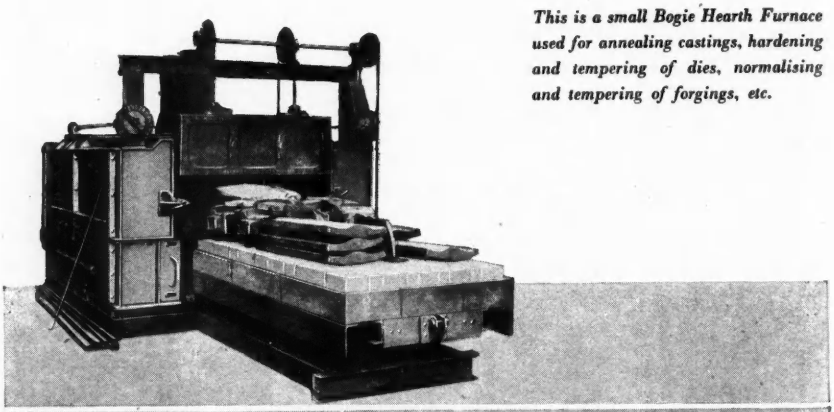


achievement . . .



The achievement of our Navies needs no emphasis . . . this Country owes its very existence to their never failing efforts to defeat the U-boats.

It is a similar story in the factory . . . a struggle for new ideas, quicker deliveries, larger outputs . . . and the name INCANDESCENT is at the forefront of progress in the field of Industrial Heat Engineering.



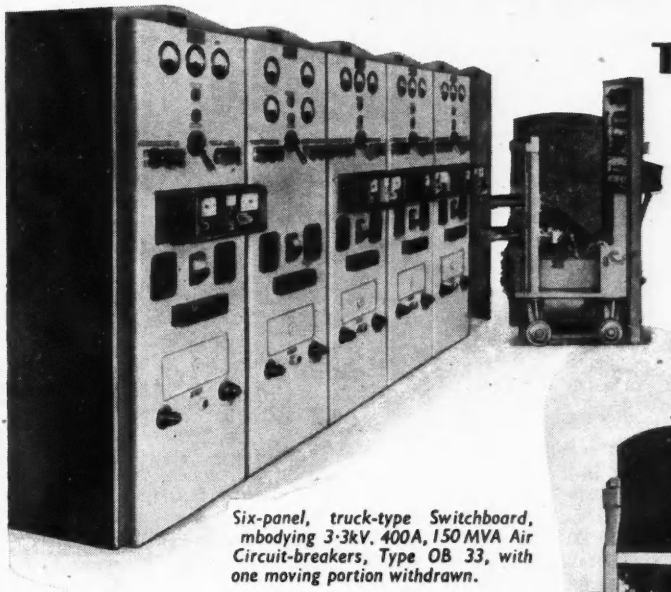
This is a small Bogie Hearth Furnace used for annealing castings, hardening and tempering of dies, normalising and tempering of forgings, etc.

Incandescent Heat Co Ltd · Furnace Engineers · Smethwick

'ENGLISH ELECTRIC'

HIGH-BREAKING-CAPACITY · HIGH-VOLTAGE

AIR-BREAK SWITCHGEAR



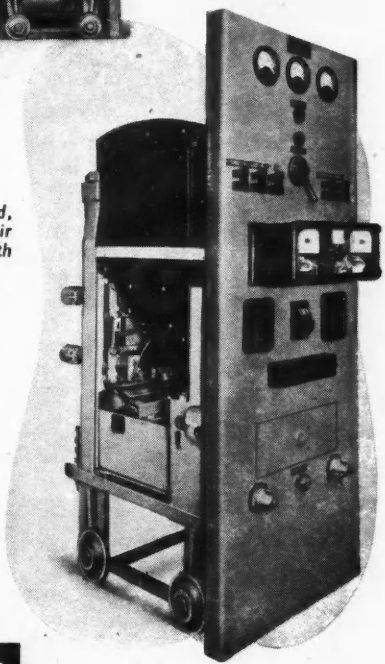
TYPE OB33
FOR VOLTAGES UP TO 3·3kV.

Six-panel, truck-type Switchboard, mbodying 3·3kV. 400A, 150 MVA Air Circuit-breakers, Type OB 33, with one moving portion withdrawn.

'English Electric' Switchgear, Type OB 33 is particularly suitable for use on high-voltage circuits with breaking-capacities up to 150 MVA, at 3·3kV.

IMPORTANT FEATURES

- Elimination of oil fire risk.
- High-pressure silver-faced butt contacts.
- Non-pitting arcing contacts.
- De-ionising arc splitters.
- Electrical operation, manual if desired.
- Truck, or fixed cubicle mounting, with fully interlocked isolation.



Larger view of a moving portion.

THE ENGLISH ELECTRIC COMPANY LIMITED
· · STAFFORD · ·

BLUE PRINT
for Post-War Planning

'Tungum' alloy is available as Rod and Bar; Sheet and Strip; Wire, Wire Rope, Gauze and Springs; Solid Drawn Tubings; Castings, Forgings, Stampings, Pressings, etc. Data Sheets have been prepared dealing with these various fabricated forms of 'Tungum.' They are free on request. Our technical staff will be pleased to answer any queries and carry out tests.

The Whole Nation is busy; doing a job that cannot wait. Though we know that Victory will give ample scope for far-reaching developments in every sphere of human activity, at the moment we have little time for post-war planning. We can, however, learn from our present problems. We can make 'marginal' notes for to-morrow's application, where to-day's use of metal suggests post-war possibilities. Many urgent problems are being solved by the use of 'Tungum,' because of the special characteristics found together in this alloy found only singly in other metals.

Wherever the strength-to-weight factor has to be considered; where ductility and resistance to torsional fatigue are important; where a high resistance to corrosion is essential; where ease of working, pleasing appearance, resiliency, thermal conductivity, and a low co-efficient of friction are desirable; 'Tungum' is worth the closest investigation. It may be the key to your problem now and in the post-war period.

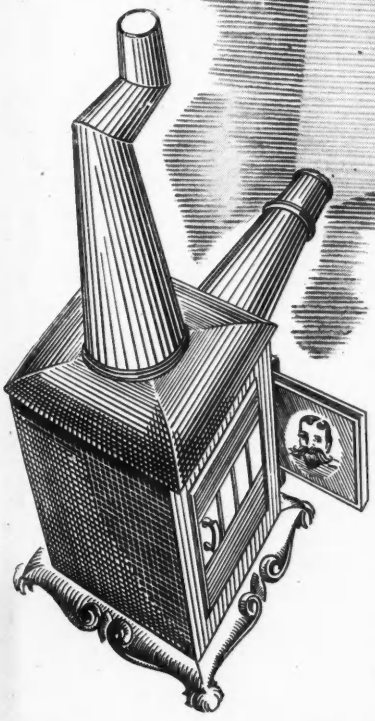
'Tungum' BRAND
Trade Mark
ALLOY

TUNGUM SALES CO. LTD.

Brandon House, Painswick Road, Cheltenham, Glos.

Magic—

BUT ··· SOMEBODY WASN'T SATISFIED



If anyone had asked an engineer of 1903 for gears of such precision as are now used in the engines that drive our planes across the skies of Europe, he would have raised his eyebrows. "Possible of course. Pigs may fly some day!"

Well, here we are in 1943. The gears are in the planes and the planes in the sky.

Holroyd have played a part in producing these 'wonderful' modern gears—but we are not sitting back. We know that in the next forty years there must be progress at least as great as in the last forty.

If you have new demands for gears; or if you think it time your Machine Tools smartened up their ideas, you may care to tell us what you want. It may sound like a 'pipe-dream' but, together, we may make it a reality of the unborn future.

H O L R O Y D

★ GEARS ★ BRONZE ★ MACHINE TOOLS ★

JOHN HOLROYD AND COMPANY LIMITED, MILNROW AND ROCHDALE, LANCASHIRE.

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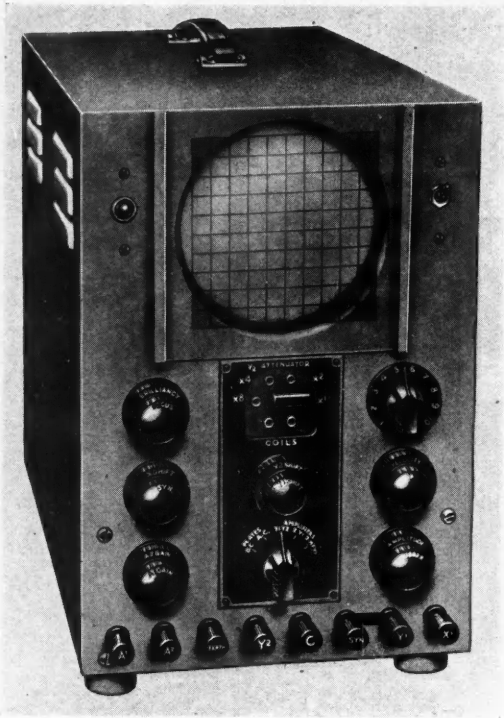

COSSOR MODEL 339

DOUBLE BEAM

OSCILLOGRAPH

This is the standard instrument produced to meet the requirements of a wide field of application. It possesses the unique advantage of simultaneous indication of two effects. A 96-page technical Instruction Manual is supplied with each instrument, or may be obtained at 3/6 (postage 3d.)

PRICE £40 NET.

Industrial Indicating and Testing

THE Cathode Ray Tube has long been established as indispensable in solving technical problems of research and production testing in the radio communications industry, where its use is of course obvious.

Not so widely recognised is the fact that it can be equally invaluable in other industries, on both electrical and mechanical tests, when the effect examined is applied to the tube as a voltage.

The inherent value of the Cathode Ray Tube lies in its being the only device capable of providing

VISUAL DELINEATION (as a stationary trace) of the law of variation in recurrent effects.

Accurate RELATIVE TIMING OF EVENTS and other comparative measurements.

As pioneers in the development and application of Cathode Ray technique our outstanding contribution is the DOUBLE BEAM tube, which has the advantage of also providing the important and unique feature of:

SIMULTANEOUS INDICATION of two variables on a common time axis.

In considering the above in relation to their own particular work, Research and Test Engineers are invited to consult our Instrument Department for expert advice.

A·C·COSSOR Ltd.

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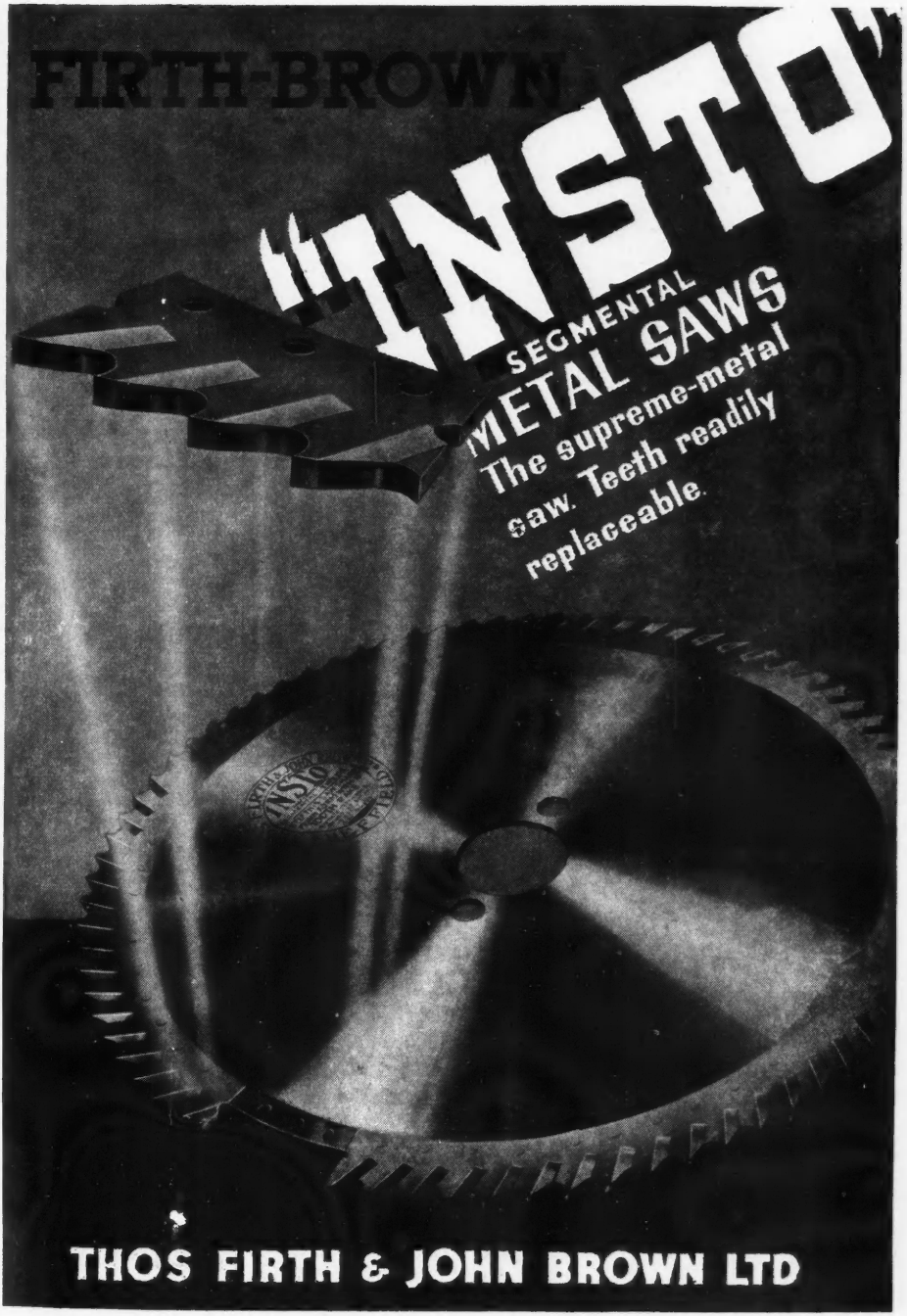
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"INSTO"
SEGMENTAL
METAL SAWS
The supreme-metal saw. Teeth readily replaceable.
THOS FIRTH & JOHN BROWN LTD

DRILLING
Wolf
Electric Tools
S. WOLF & CO. LTD., PIONEER WORKS, HANGER LANE, LONDON, W.5. PERivale 5631-3
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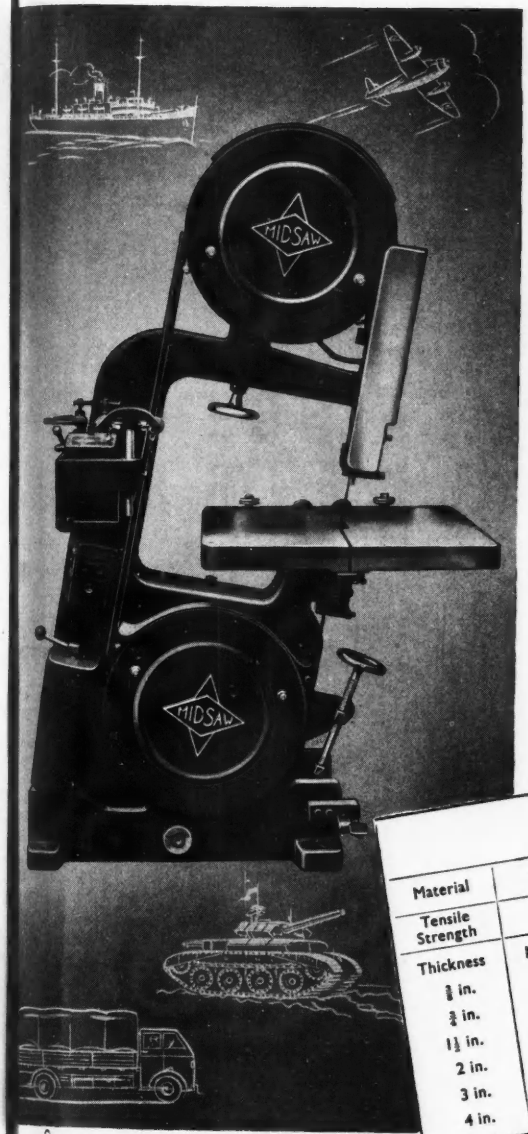

See what a MIDSAW can save . . .

THE chart set out below will keenly interest every manufacturer out for the highest economy in the production of Dies, Press Tools, Templets, Gauges and other Tool Room work.

MIDSAW, the Miracle Worker, saws and files the hardest modern metals, both regular and irregular shapes with a speed and accuracy impossible by any other method, and—it achieves this with unskilled and inexperienced operators.

The MIDSAW Tool Room Bandsaw and Bandfile Machines cut out laborious drilling, chiselling, chipping and hand-filing methods which put a brake on output and increase production costs. Our Technical Advice Service will be happy to advise you—write us.

CUTTING TIMES
Per Inch Length of cut

Material	Mild Steel		Carbon		Nickel Chrome Steel	
Tensile Strength	30 tons		45 tons		65 tons	
Thickness	Mins.	Secs.	Mins.	Secs.	Mins.	Secs.
⅜ in.		20		30		50
½ in.		35		50	1	10
¾ in.		50	1	15	2	50
1½ in.	1	45	2	—	3	35
2 in.	2	—	2	45	5	45
3 in.	3	20	3	45	7	—
4 in.						

MIDSAW *Write for our Illustrated Brochure of Metal Cutting Machines*

THE MIDLAND SAW & TOOL CO. LIMITED
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GACO is *ideal* for hydraulic sealing being grainless, resilient, non-porous and *highly* resistant to oils, fuels and chemical corrosives. It is *widely used* in the hydraulic and pneumatic control systems of aircraft where only materials of the *highest* grade can be employed. Its unequalled surface finish and dimensional accuracy is well known to all designers.

Our staff of qualified technical specialists is at your service. Consult us and we will solve your sealing problems.

HYDRAULIC PACKINGS SEALS · GASKETS

SYNTHETIC GACO RUBBER

REGD. TRADE MARK

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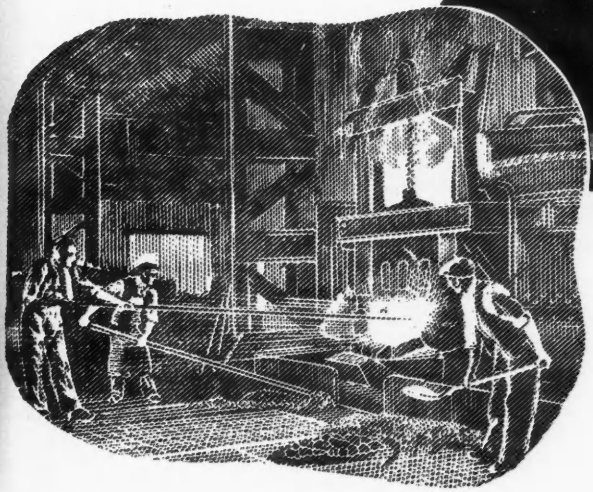
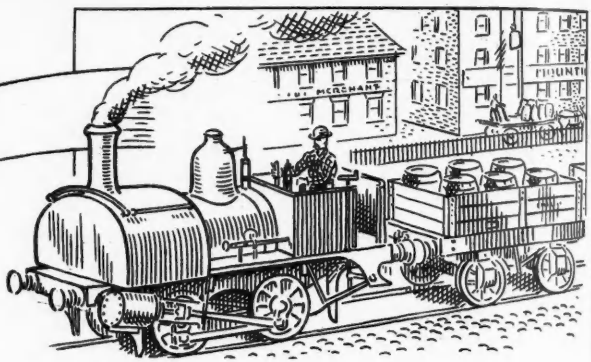
SKILLED
WORKERS

The
STEEL-
MELTER
(SOTOH ELECTRIC FURNACE)



ENGLISH STEEL CORPORATION LTD.
STEEL MANUFACTURERS VICKERS WORKS SHEFFIELD

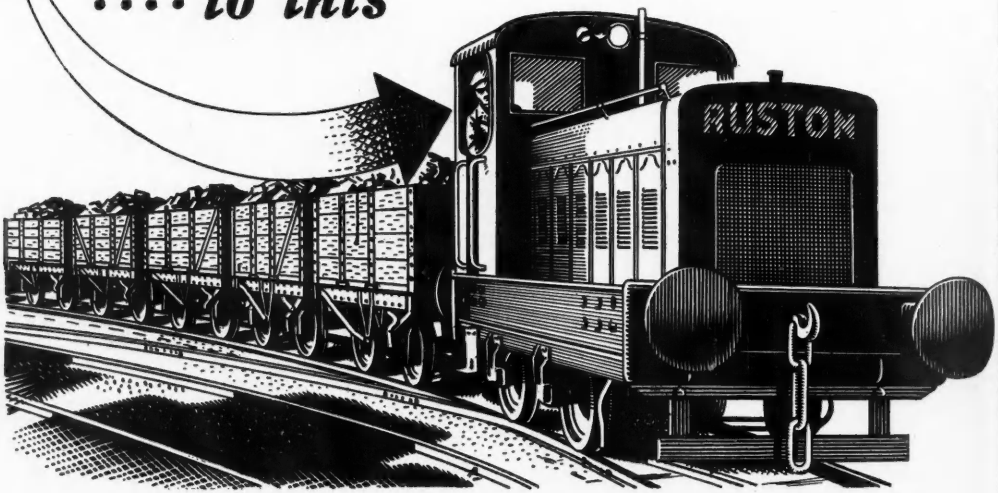
from this —



In 1868 Ruston Proctor & Co. built their first Steam Locomotives —an order for five, weighing 36 tons each, supplied to the Great Northern Railway for shunting duties.

In 1943 Ruston Locomotives, now powered with Ruston Oil Engines, are used for a great variety of duties including haulage on sidings, Public Works Contracts, in Quarries, Brickyards and Coal Mines, both on the surface and underground.

.... to this



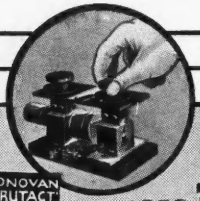
RUSTON & HORNSBY LTD • LINCOLN

A pressure of one finger on the Permutit Fully Automatic Water Softener control, ensures a constant flow of Zero Soft Water.

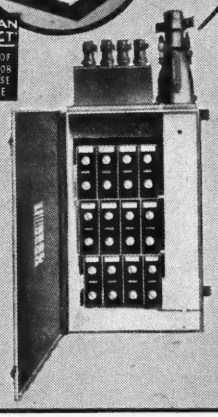
This finger-tip efficiency not only saves material and time, but enables your plant to be operated with a minimum of labour—a factor to be considered in days of war.

Prepare now, too, for the demands that will be made on industry in the days that are to come, by writing to The Permutit Co. Ltd., Dept. T.B. Permutit House, Gunnersbury Avenue, Chiswick, W.4, Telephone Chiswick 6431, for our Publication No. 23, which fully describes the Permutit Fully Automatic Water Softening Plant.

with **Permutit**
Fully Automatic
Water Softeners



DONOVAN SCRUTACT
ONE TURN OF KNURLED KNOB CLAMPS FUSE CARTRIDGE



The FINGER & THUMB method of

1. Removing blown H.R.C. Cartridges instantly without tools. 2. Fixing new cartridge and getting maximum contact pressure. No "springy" contacts; no overheating. One turn of knurled knob clamps or releases bridge. Write for full particulars.

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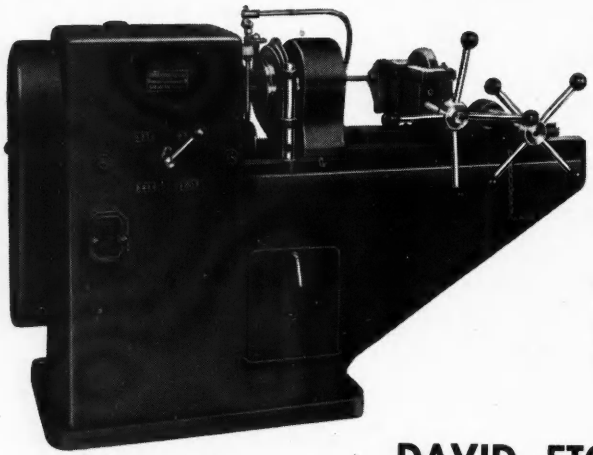

This range of machines has the following features :

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(2) Totally enclosed gear box fitted with Ball and Roller Bearings.

(3) Our well known self-centring adjustable vice.

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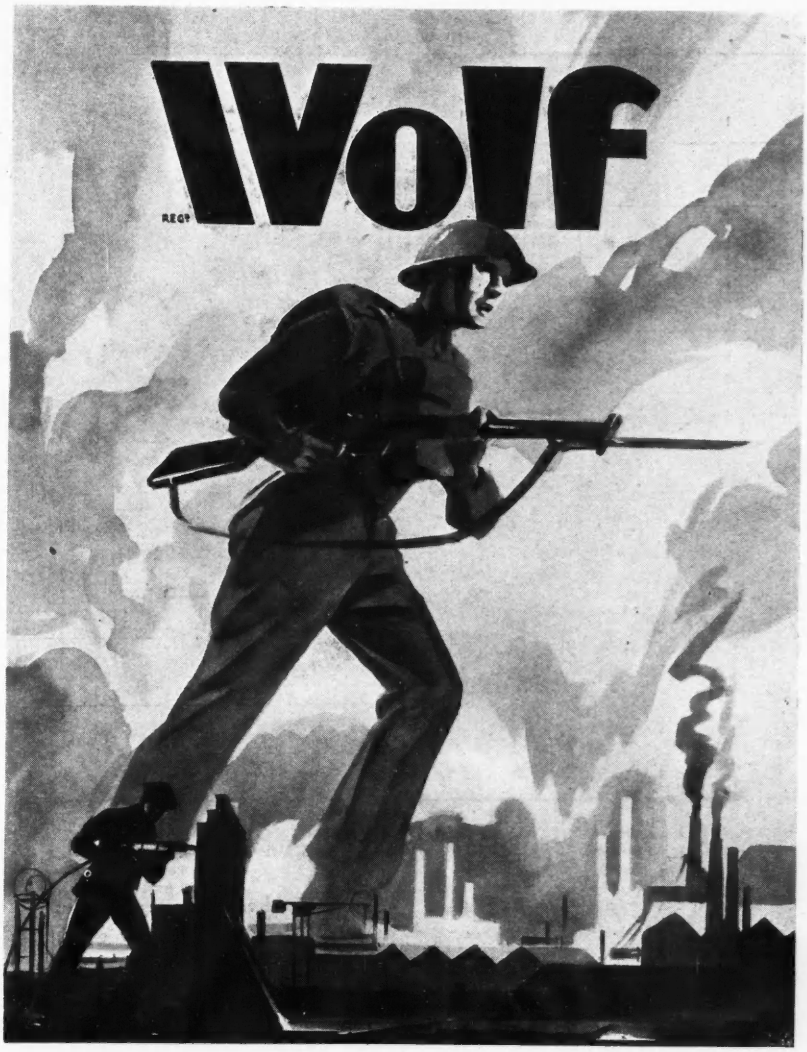

Christmas Greetings

TO FRIENDS ON ALL FRONTS

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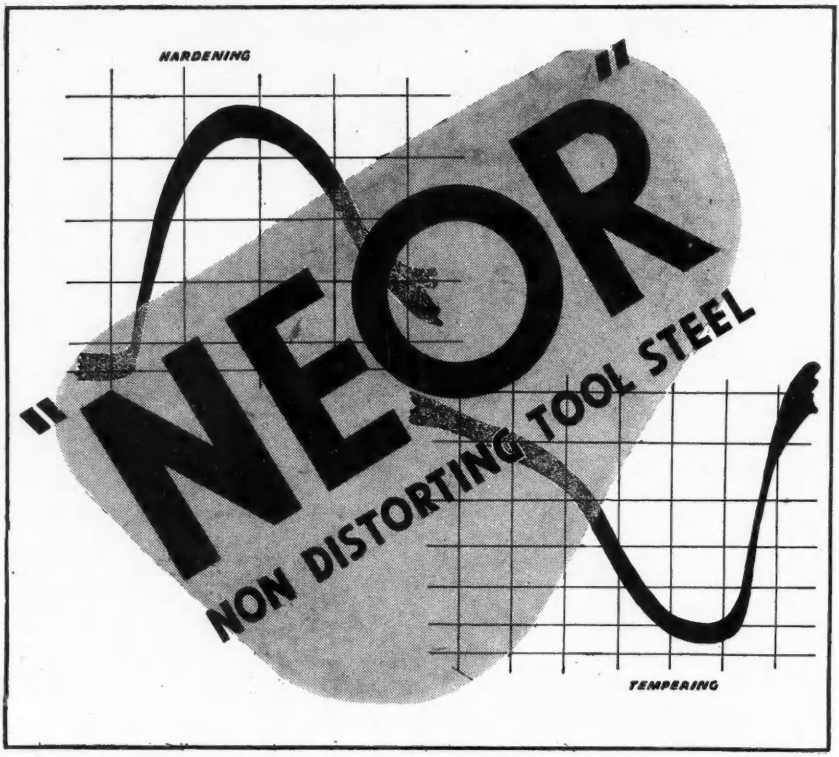

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'Neor' is the original non-distorting, non-shrinking tool steel which resists wear and gives good resistance to abrasion. Its simple heat-treatment ensures uniform hardening and it can be relied upon to retain its shape during heat treatment.

Recommended for all types of press tools, punches, dies and other similar duties. Gives remarkably clean cuts free from gash and retains its non-sinking edge for long production runs. 'Neor' has been called "the almost perfect tool steel."

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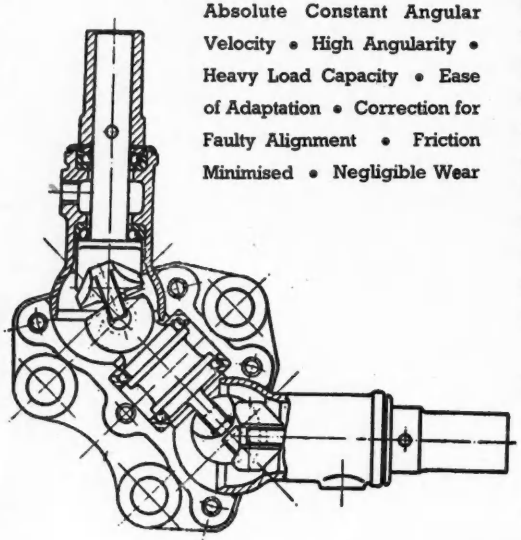

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and PLASTICS

It is a pity that when new materials come along there is always somebody who wants to make them look what they're not. You couldn't have anything much more satisfactory than the smooth finish and beautiful colour of many plastic articles yet so often have there been attempts to make them look like walnut, mahogany, marble, or some other natural material. Some BEETLE mouldings have been described as "imitation ivory" simply because they are ivory in colour and are smooth and lustrous—you might just as well call anything black, "imitation jet."

All this is a pity because BEETLE is not an imitation or a substitute for anything—it is a modern material quite able to stand up for itself on its own merits. It has its limitations like everything else. It is much cheaper than the rare materials but more expensive than the common. Choose Plastics for the jobs they can do best. choose them for their own attractiveness and not because they can be made to look what they're not.

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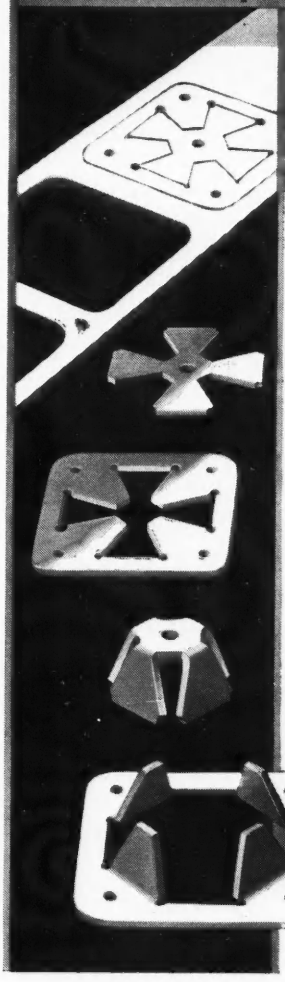
RUBBER-TO-METAL WELD
plus Scientific application



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But the attractions of that manufacturing technique must not be allowed to obscure the fundamental requirement;

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That knowledge we possess; it is at the disposal of all who have vibration problems, and it is always increasing.

The photographs show stages in the manufacture of our patent 'cross'-type mounting: the smallest size is suitable for instruments and carries a pound load, the largest, for heavy machines, carries a ton; this range covers a variety of frequencies.

This simple design has outstanding features; the bonding areas on inner and outer members are equal, stress concentrations are avoided; the rubber is stressed in shear, and is thus used to the best advantage.

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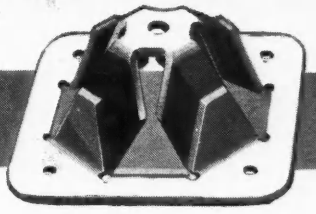

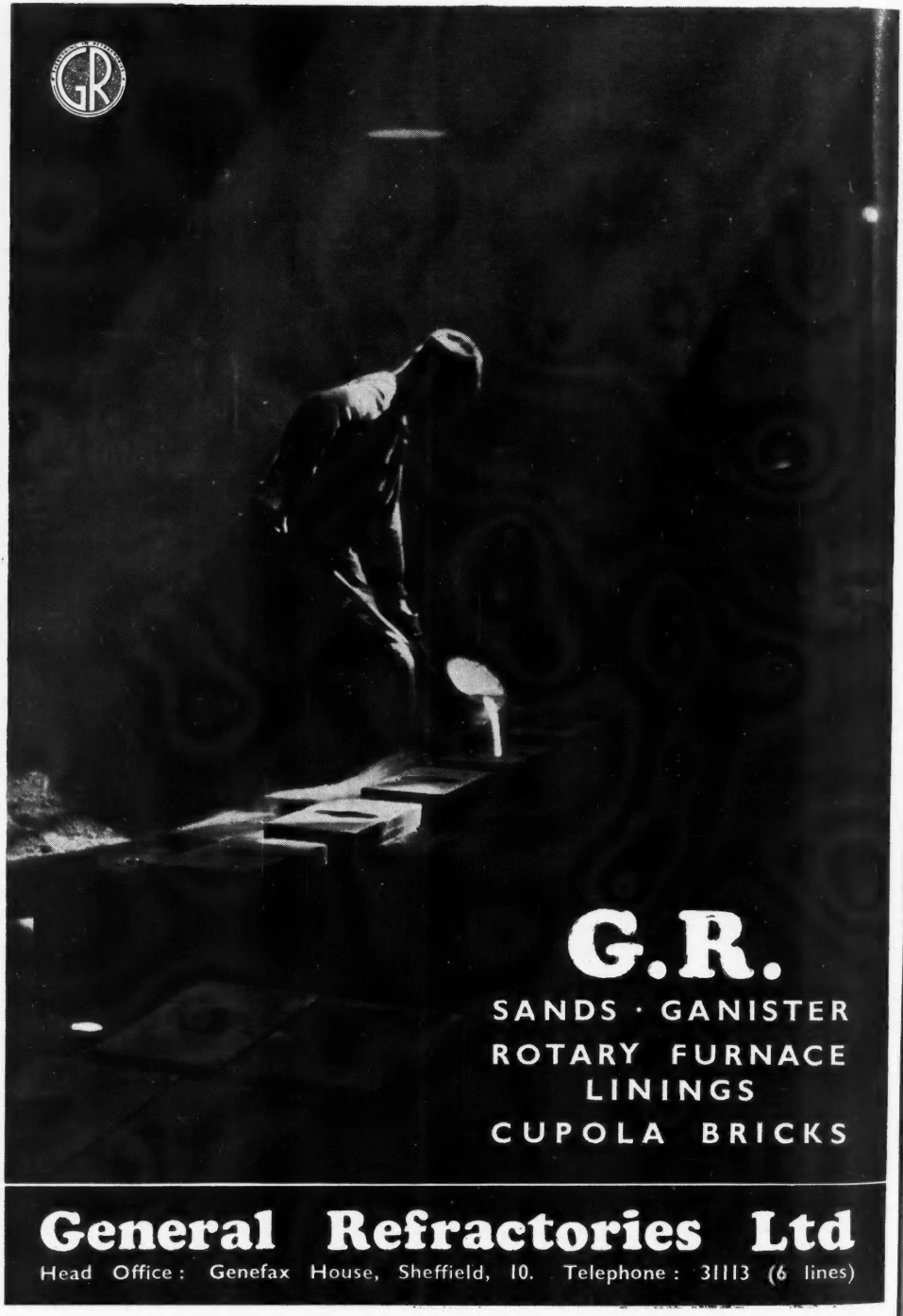
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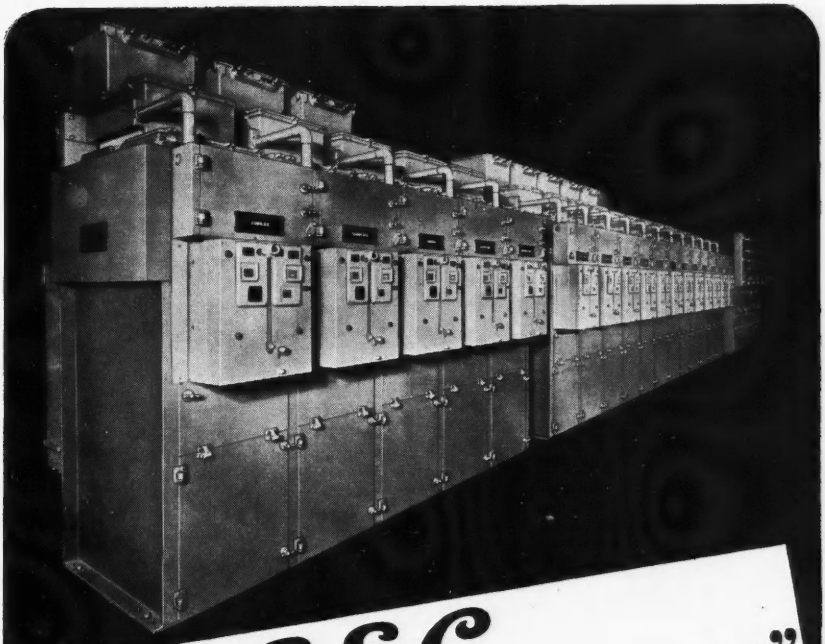

Three boards comprising 22 panels 11 kV "SUBGEAR" for a large municipality. Breaking capacities from 150 to 350 MVA.

G.E.C. METALCLAD "SUBGEAR"

G.E.C. "SUBGEAR" is eminently suitable for installation in every type of substation.

It is available up to a maximum voltage of 11 kV and for breaking capacities from 75 to 350 MVA.

All units are rigorously tested in conformity with British Standard No. 116/1937.

Salient features of "SUBGEAR" *include :—*

VERTICAL ISOLATION, with resultant saving of space and general simplification.

EASE OF MAINTENANCE, accessibility of all parts simplifies inspection, maintenance, cable jointing, etc.

"SUBGEAR" is fully described in pamphlet T.D. No. 334. Copy free on request.

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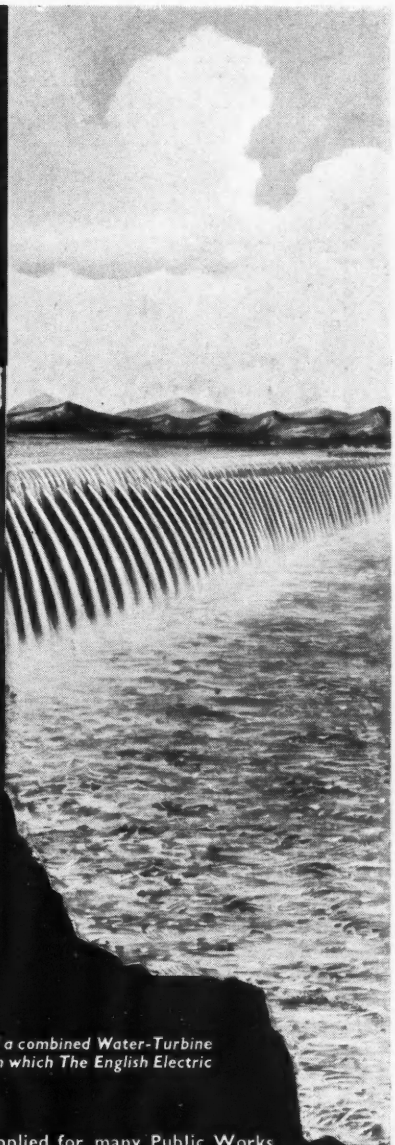
Hydro-Electric Plant

Three Vertical Shaft 17,400 H.P. Water-Turbine Sets



A typical example of a combined Water-Turbine and Generator Unit in which The English Electric Company specialize.

The Company's equipment has been supplied for many Public Works and other important installations throughout the world, including: Great Britain, Australia, Canada, India, Newfoundland, New Zealand, South Africa, Argentina, Brazil, Eire, Federated Malay States, Mauritius, Nepal, New Guinea, Nigeria, Portugal, Turkey.

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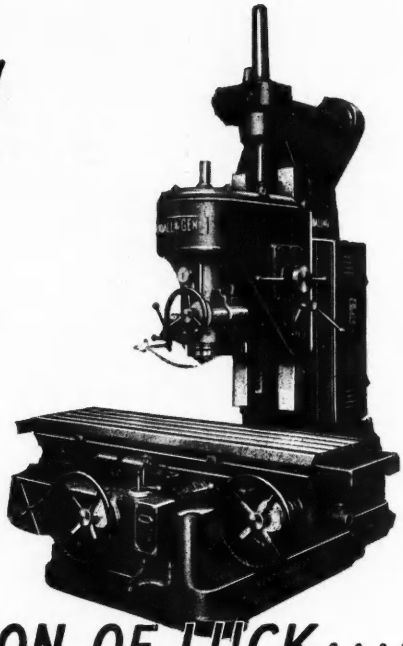
Progress



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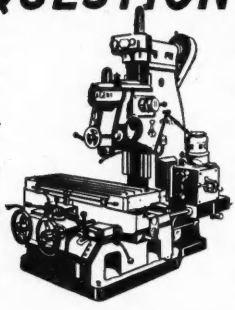

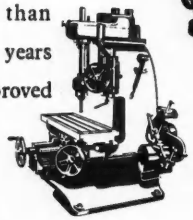

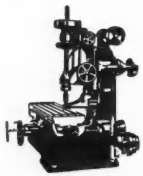

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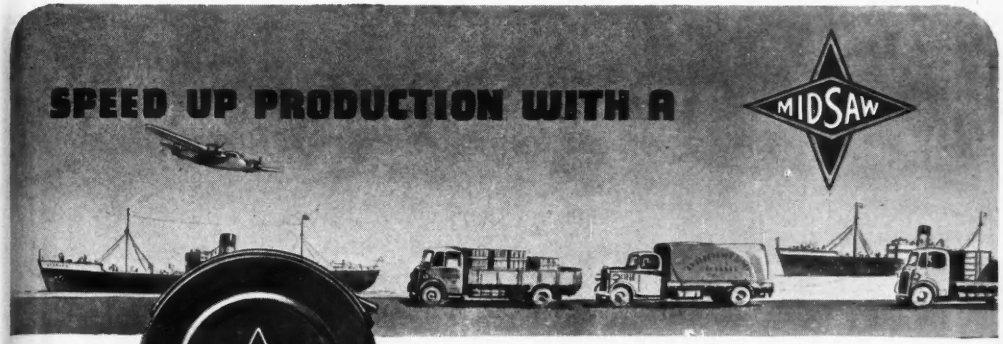

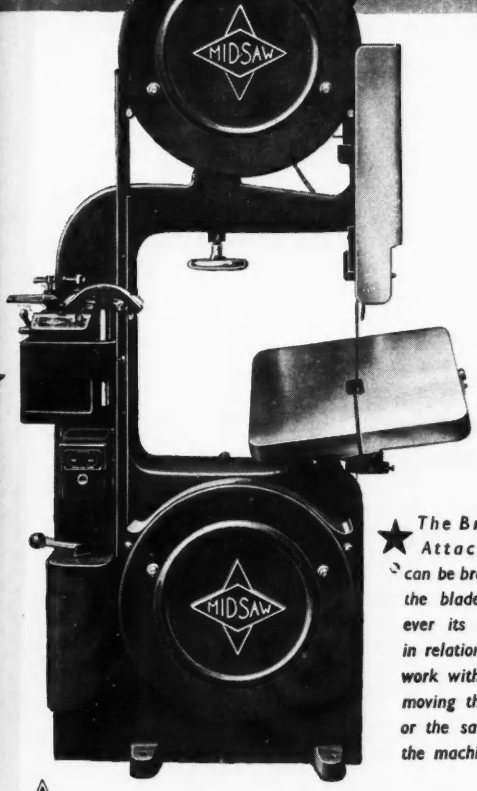

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Are you doing jobs on a lathe, a shaper or a drilling machine that could be carried through quicker and better on a more suitable and less expensive

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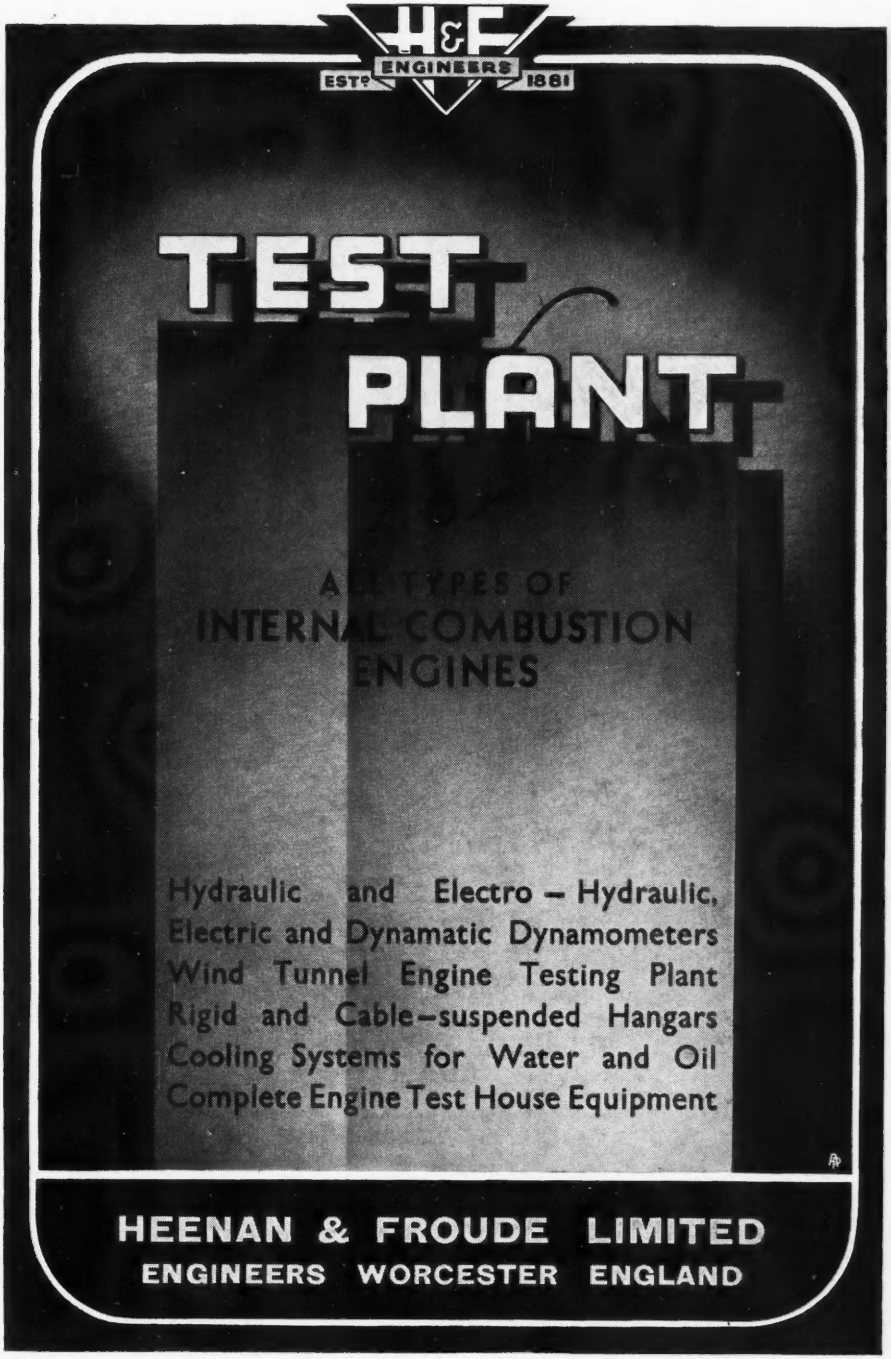
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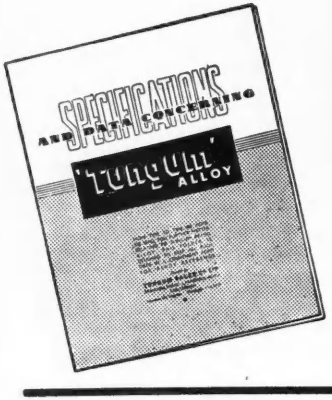

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Tungum Alloy is described in Technical Data Sheets under headings—Tubing; Rod and Bar; Sheet and Strip; Wire; Cables; Gauzes and Springs; Castings; Pressings. They are available free on request.

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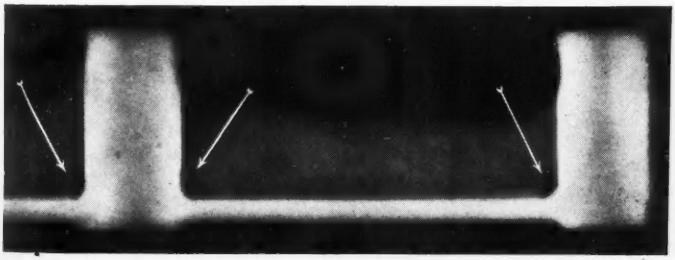
—*but is it sound?*

This photograph shows in its entirety the casting part of which (excluding the bracket portion) is covered in the radiograph.

The detection of gross defects in castings serves two purposes of prime importance. It obviates the wasting of expensive machining on defective castings, and it eliminates castings which may fail in service. Thus X-ray inspection is an essential form of industrial insurance.

In the example illustrated, the X-ray examination of a steel casting reveals shrinkage at the changes of section, in the form of the dark shadows indicated by arrows.



According to the material of the casting and the type of defect which it is necessary to detect, exposures without screens, with lead screens or with fluorescent screens may be most suitable. The appropriate supplies for all circumstances—films, screens and cassettes—are available in the ' Industrex ' range.

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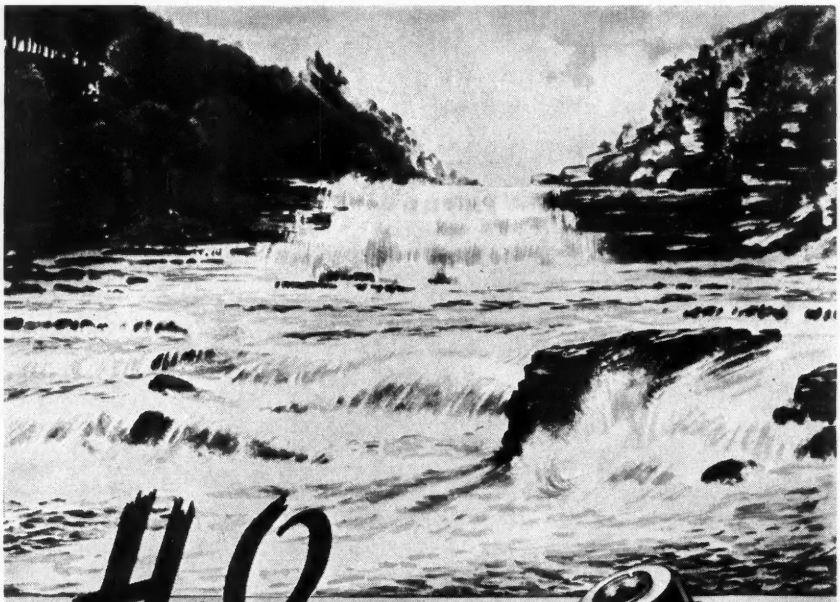

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The most important substance in the World with a thousand dangers if it is found where it has no right to be. You know what it is . . . of course you do, "WATER"—water in pipe lines, machine tools, spray plants, sandblast machines and a thousand other air uses, is a cause of endless trouble . . . LOSS OF POWER . . . FREEZING . . . WEAR . . . SPOILT PROCESSES . . . Etc., Etc.

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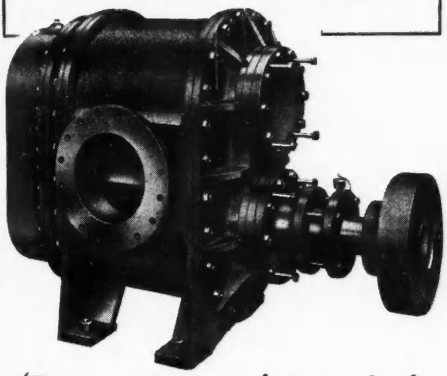

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A consideration of the following points will show why "DRUM" Pumps are continually being called upon to meet so many different needs, in all branches of industrial pumping :—

- Will pump thin or thick liquids.
- Suitable for high or low speeds.
- Positive action.
- Continuous flow.
- Can be steam-jacketed.
- Valveless and no air vessels.
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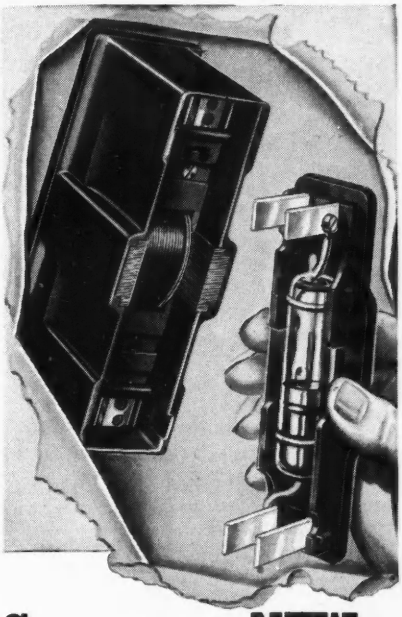

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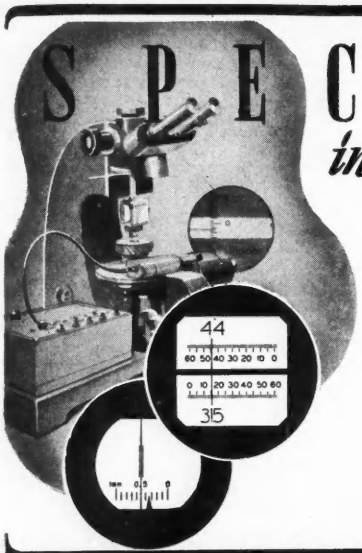

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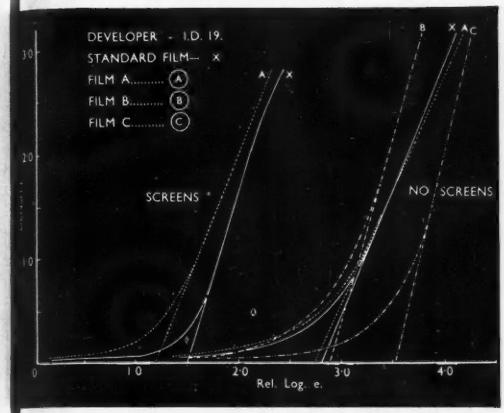

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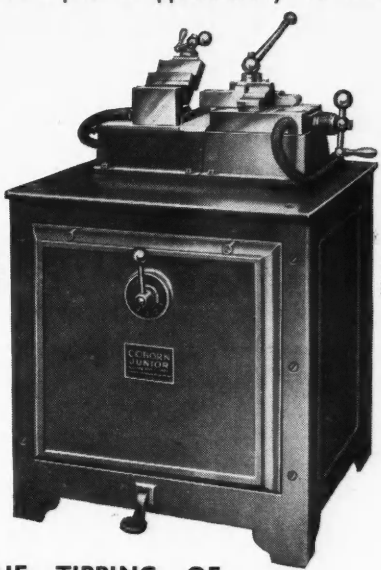

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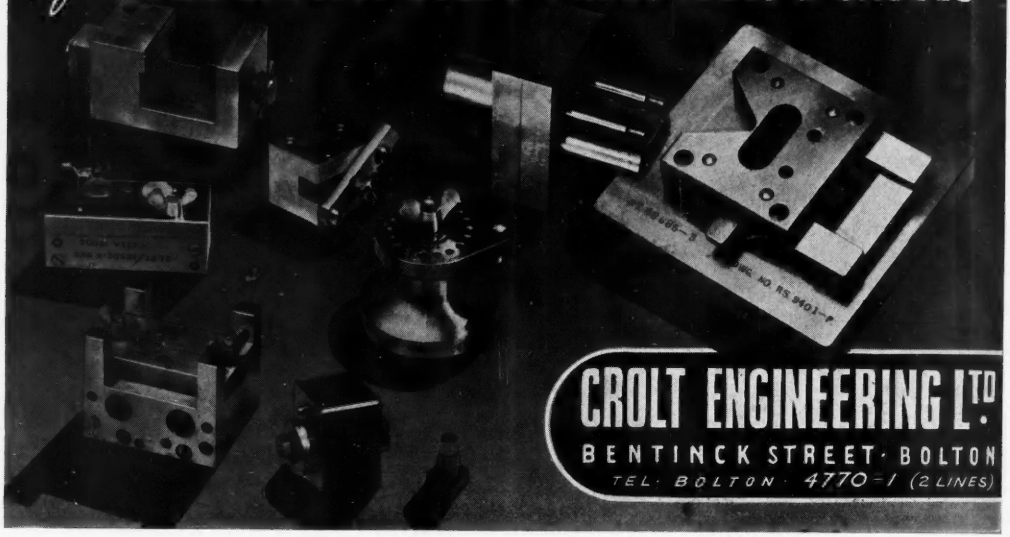

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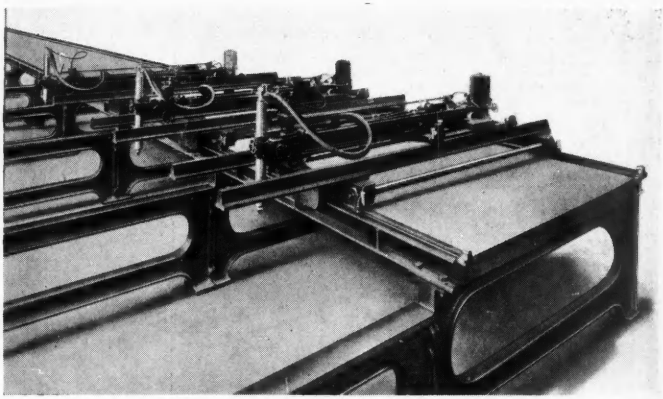

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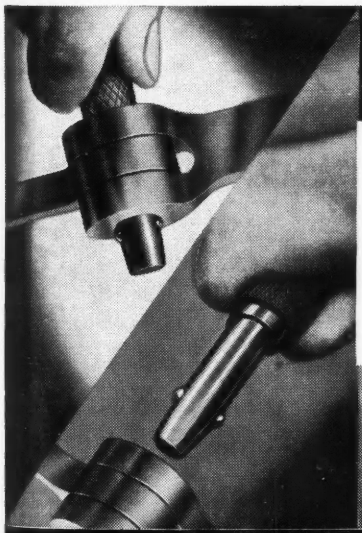

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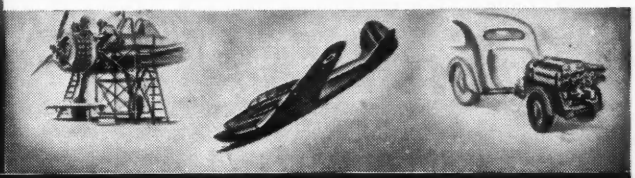

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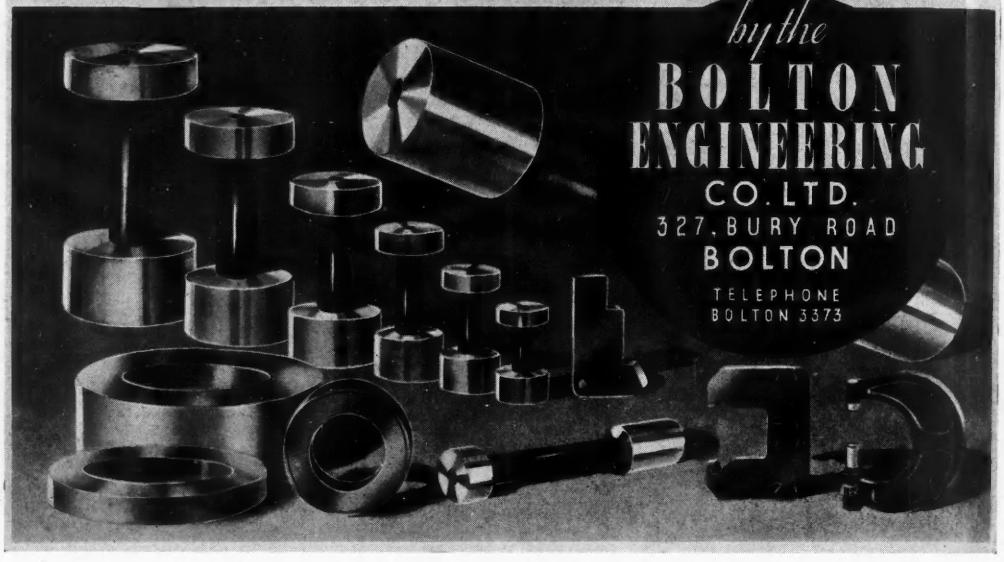

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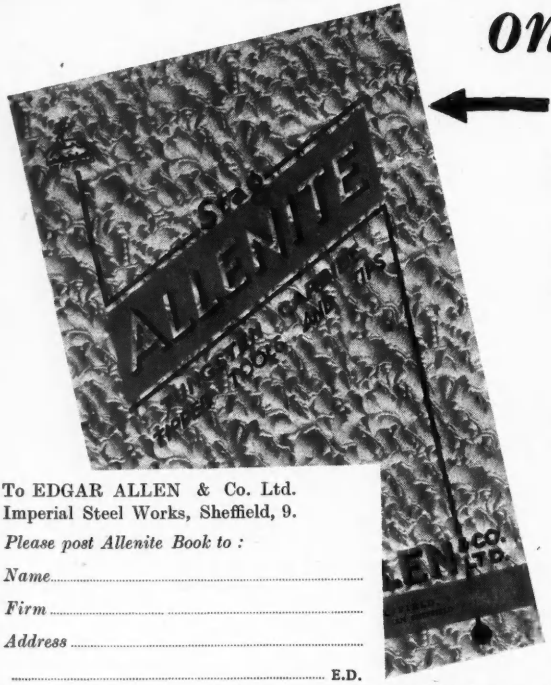

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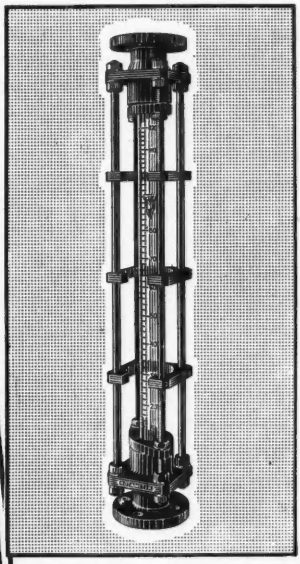

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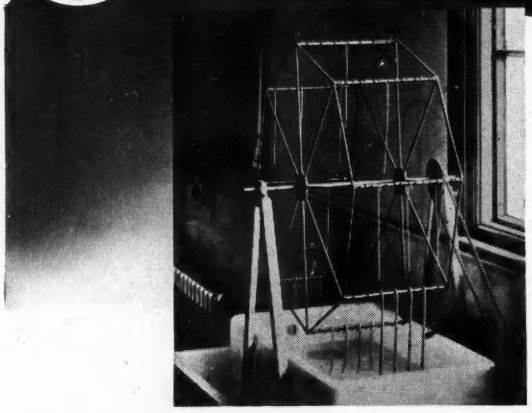

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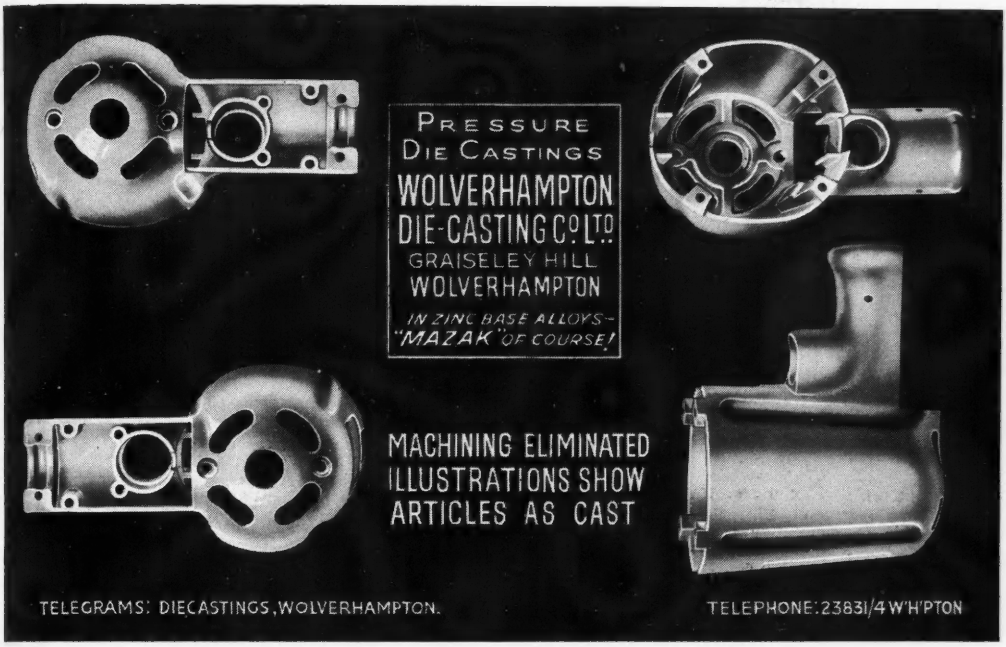
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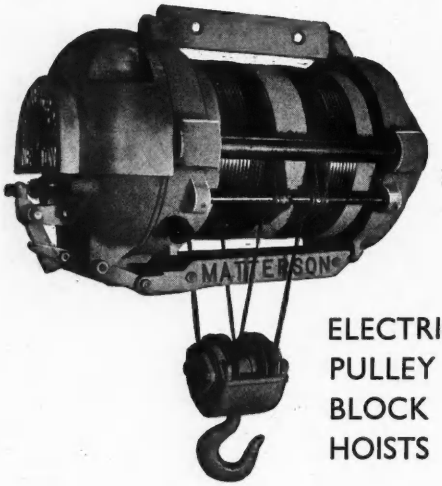

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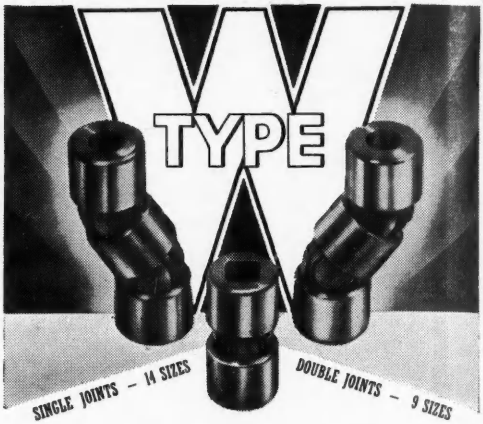

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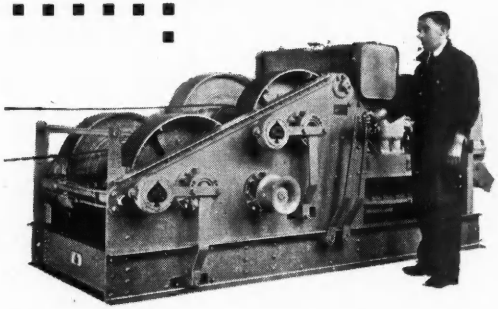

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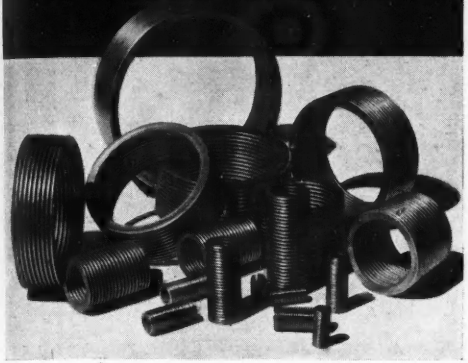

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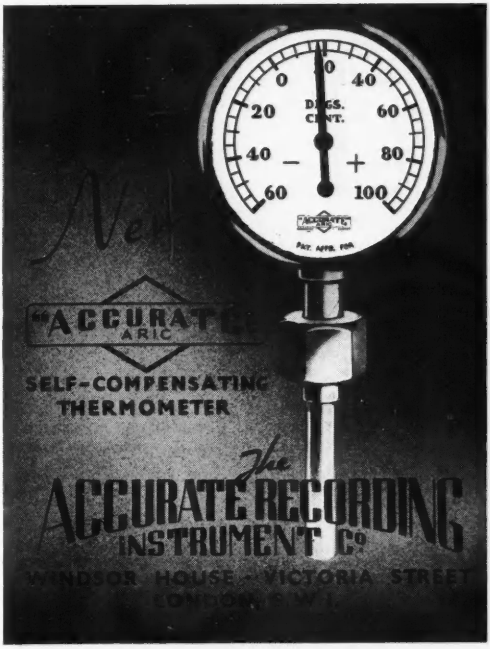

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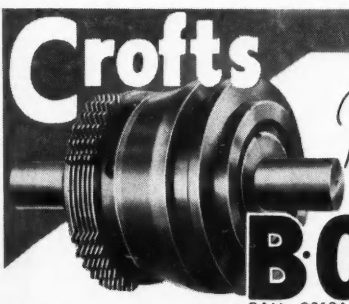

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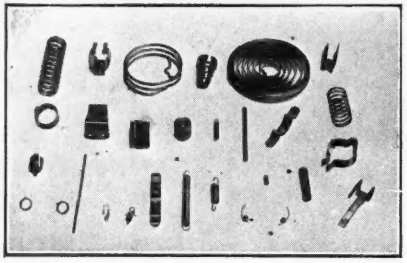

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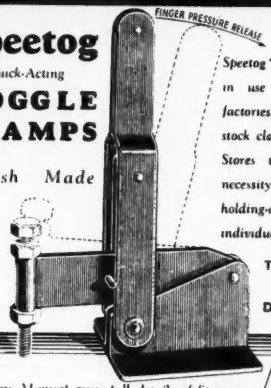

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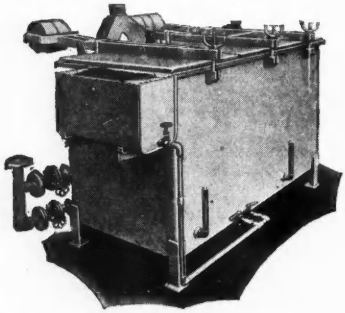

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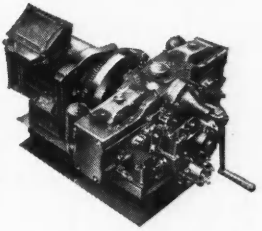

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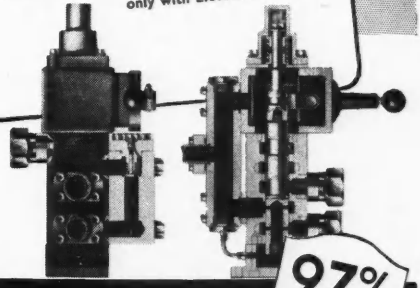

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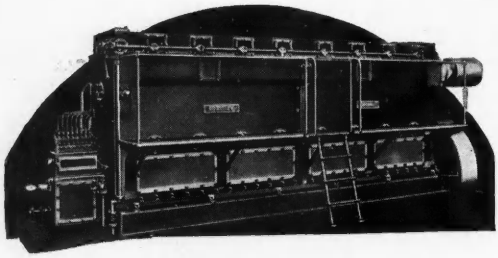

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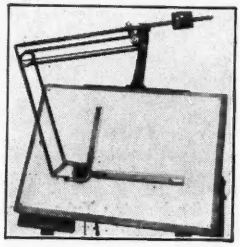

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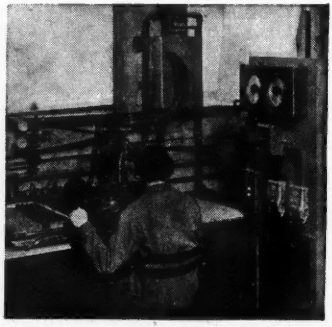

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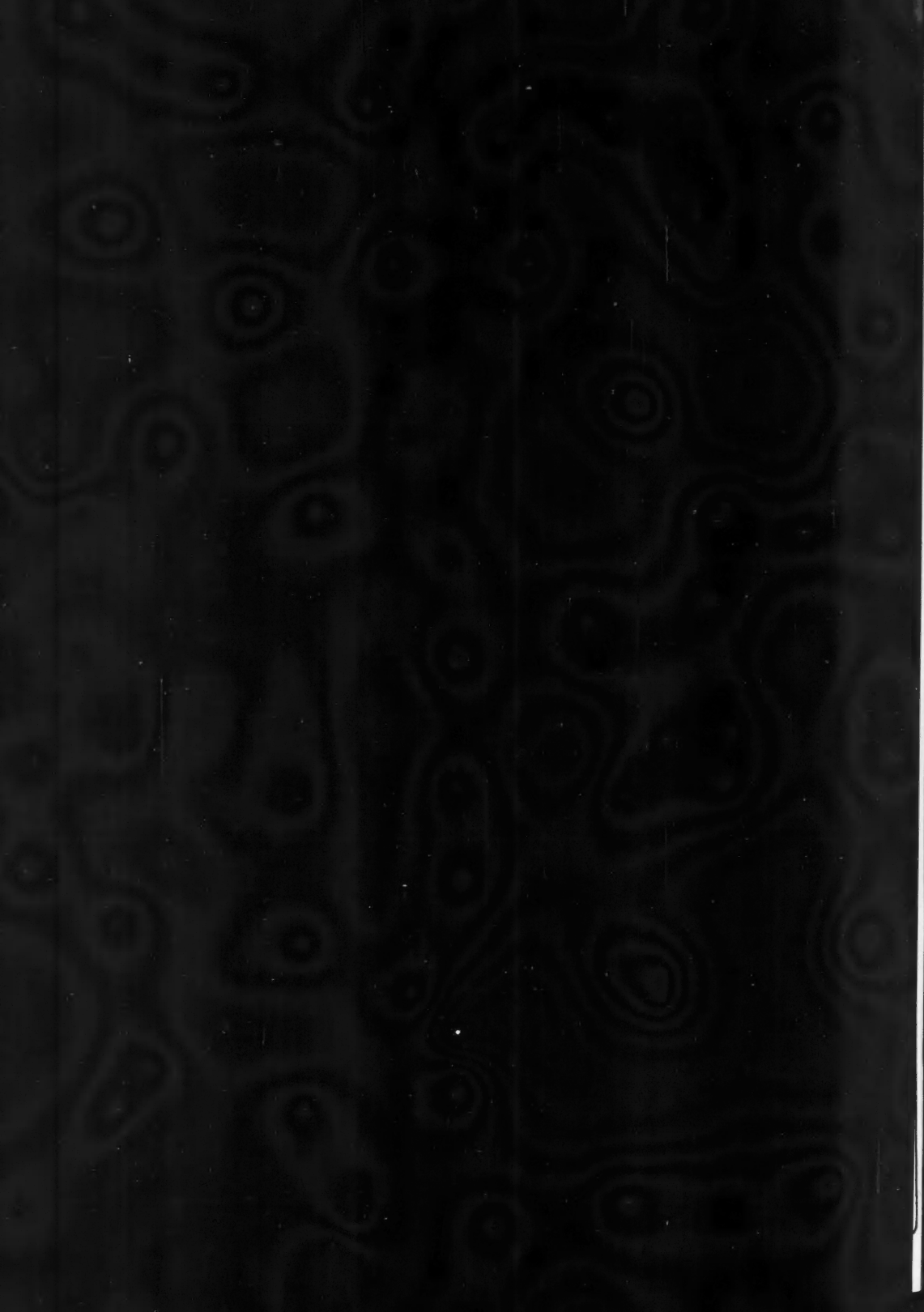

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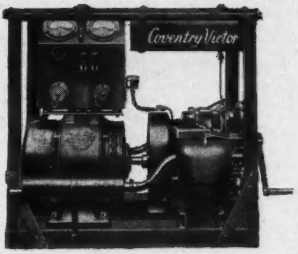

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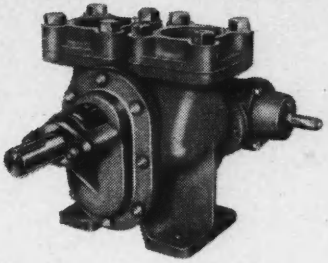

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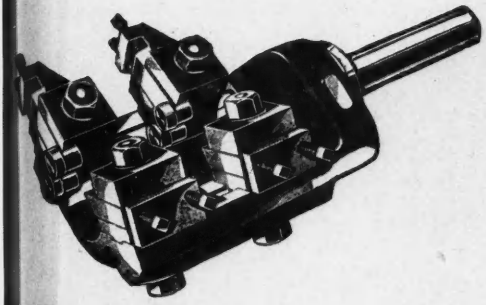

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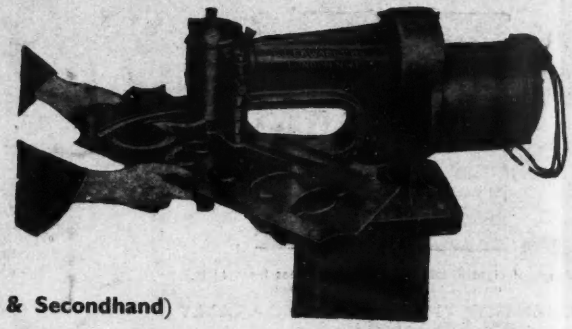

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